VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ
ÚSTAV VÝKONOVÉ ELEKTROTECHNIKY A ELEKTRONIKY

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
DEPARTMENT Of POWER ELECTRICAL AND ELECTRONIC ENGINEERING

OPTIMALIZACE ENERGETICKÝCH PARAMETRŮ ASYNCHRONNÍCH STROJŮ MALÉHO VÝKONU

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE João Pepino Ndembe Chincocolo

AUTHOR

BRNO 2011

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ
ÚSTAV VÝKONOVÉ ELEKTROTECHNIKY A ELEKTRONIKY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
DEPARTMENT Of POWER ELECTRICAL AND ELECTRONIC ENGINEERING

OPTIMALIZACE ENERGETICKÝCH PARAMETRŮ ASYNCHRONNÍCH STROJŮ MALÉHO VÝKONU

OPTIMALIZATION POWER PARAMETER OF SMALL INDUCTION MOTORS

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE João Pepino Ndembe Chincocolo
AUTHOR

VEDOUCÍ PRÁCE prof. Ing. VÍTEZSLAV HÁJEK, CSc
SUPERVISOR

BRNO, 2011

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
Fakulta elektrotechniky a komunikačních technologií
Ústav výkonové elektrotechniky a elektroniky

Bakalářská práce

bakalářský studijní obor
Silnoproudá elektrotechnika a výkonová elektronika

Student: *João Pepino Ndembe Chincocolo* **ID:** *119451*
Ročník: *3* **Akademický rok:** *2010/11*

NÁZEV TÉMATU:

Optimalizace energetických parametrů asynchronních strojů malého výkonu

POKYNY PRO VYPRACOVÁNÍ:

1. Zpracujte přehled typů malých asynchrnních motorků.
2. Proveďte rozbor jednoho konkrétního typu stroje
3. Navrhněte možnosti zvýšení účinnosti.

Dle dopuručení vedoucího

DOPORUČENÁ LITERATURA:

Termín zadání: *10.10.2010* **Termín odevzdání:** *30.05.2011*

Vedoucí projektu: *Prof. Ing. Vitezslav Hájek, CSc.*

doc. Ing. Petr Toman, Ph.D.
předseda oborové rady

Abstrakt

Tato bakalářská práce “Optimalizace energetických parametrů asynchronních strojů malého výkonu“ popisuje testovací metody, potřebné ke stanovení ztrát a účinnosti elektrických strojů, se zaměřením na asynchronní stroje. Určuje výpočetní postupy pro vyhodnocení daných měření. Definice uvedených zkoušek jsou sepsány se zřetelem na současné normy. Z informací obsažených v částech s výše uvedeným obsahem vychází prakticky zpracovaný nástroj pro samočinné vyhotovení protokolu z měření. Jedná se o formulář v elektronické podobě. Vstupem formuláře jsou zadané naměřené hodnoty. Výstupem formuláře je protokol o měření, uvádějící výsledky výpočtů a grafy charakteristik. Pro účely této bakalářské práce byl formulář předvyplněn naměřenými hodnotami ze zkoušek konkrétního asynchronního stroje. Související výpočty k určení parametrů stroje jsou uvedeny.

Abstract

This thesis "Optimalization Power Parameter of Small Induction Motors "describes the test methods needed to determine losses and efficiency of electric machines, with a focus on induction machines. The author discusses the losses in iron circuits, additional losses, mechanical losses measurement of short-circuit, open circuit, electric machines. Definitions of those tests are written with respect to current standards. The measurement information contained in the above sections follow to practical tool for automatic processing of the original report. It is an electronical form. Entry data of the form are measured values. The output is a report of measurement, indicating results of calculations and graphs of characteristics. For purposes of this work the form was pre-filled with measured results of the specific induction machine. Related calculations determining the machine parameters are given.

Klíčová slova

Měření nakrátko, naprázdno, normy, měření, stroje, zatěžovací, ztráty.

Keywords

Measurement of short-circuit, open circuit, standards, measurement, machines, loading, loss.

Bibliografická citace

CHINCOCOLO, JOÃO P. Nd. Optimalizace energetických parametrů asynchronních strojů malého výkonu. Brno: Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, 2011. 38 s. Vedoucí bakalářské práce prof. Ing. Vítězslav Hájek, CSc.

Prohlášení

Prohlašuji, že svou bakalářskou práci na téma Optimalizace energetických parametrů asynchronních strojů malého výkonu jsem vypracoval samostatně pod vedením vedoucího bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.
Jako autor uvedené bakalářské práce dále prohlašuji, že v souvislosti s vytvořením této bakalářské práce jsem neporušil autorská práva třetích osob, zejména jsem nezasáhl nedovoleným způsobem do cizích autorských práv osobnostních a jsem si plně vědom následků porušení ustanovení § 11 a následujících autorského zákona č. 121/2000 Sb., včetně možných trestněprávních důsledků vyplývajících z ustanovení § 152 trestního zákona č. 140/1961 Sb.

V Brně dne .... Podpis autora ....

Poděkování

Děkuji vedoucímu bakalářské práce Prof. Ing. VÍTEZSLAVU HÁJKOVI, CSc za účinnou metodickou, pedagogickou a odbornou pomoc a další cenné rady při zpracování mé bakalářské práce. Za cennou pomoc rovněž děkuji Ing. Mustafovi O. E. Aboelhassanovi a všem ostatním, kteří mi věnovali svůj čas.

V Brně dne .... Podpis autora ....

CONTENTS

LIST OF FIGURES

LIST of TABLES

ABBREVIATIONS AND SYMBOLS

AC	alternating current
AM	asynchronous machine
A_1 - A_2 and B_1 - B_2	magnetic flux density, vector [V s/m2], [T]
B_r	flux density [T]
B_{sat}	saturation flux density [T]
B	temperature class 130˚ C
B_1 - B_2	commutating pole winding of a DC
b	width [m]
b_{0c}	conductor width [m]
b_c	conductor width [m]
b_d	tooth width [m]
b_{dr}	rotor tooth width [m]
b_{ds}	stator tooth width [m]
b_r	rotor slot width [m]
b_s	stator slot width [m]
b_v	width of ventilation duct [m]
b_0	slot opening [m]
C	capacitance [F]
C	temperature class >180˚ C
C_1 - C_2	compensating winding of a DC machine
Cf	friction coefficient
C	specific heat capacity [J/kg.K]
cth	heat capacity
CTI	Comparative Tracking Index
Cv	specific volumetric heat [kJ/Km3]
D	electric flux density [C/m2]
DC	direct current mature winding
P_{in}	input power [W]
PAM	pole amplitude modulation
PMSM	permanent magnet synchronous machine
PWM	pulse width modulation
P1, Pad, P	additional loss [W]
Pr	Prandtl number
Pρ	friction loss [W]
p	number of pole pairs
p_{Al}	aluminum content
pd	partial discharge
R	resistance [Ω]
R_{bar}	bar resistance [Ω]
RM	reluctance machine
RMS	root mean square
Rm	reluctance [A/V s = 1/H]
R_{th}	thermal resistance [K/W]
U	voltage [V], RMS

U	depiction of a phase
U_m	magnetic voltage [A]
U_{sj}	peak value of the impulse voltage [V]
U_v	coil voltage [V]
U_1	terminal of the head of the U
U_2	terminal of the head of the U
U	voltage, instantaneous value u(t) [V]
ub1	blocking voltage of the oxide layer [V]
u_c	commutation voltage [V]
um	mean fluid velocity in tube [m/s]
V	volume [m3]
Vm	scalar magnetic potential [A]
WR	energy returning to the voltage source
W1	terminal of the head of the W
$W\Phi$	magnetic energy [J]
X	reactance [Ω]
xm	relative value of reactance
y_φ	coil span of full-pitch winding
y_n	coil span in slot pitches

1 Introduction

Induction machines are used most often as engines. Electric motors are the most ever and are used mainly because they are the simplest of all electric, cheapest, are also operating reliable and require little maintenance. They are used for drives devices such as pumps, fans, compressors, conveyors, cranes, elevators, machine tools.

The level of prosperity of a community is related to its capability to produce goods and services. But producing goods and services is strongly related to the use of energy in an intelligent way. Motion and temperature (heat) control are paramount in energy usage. Energy comes into use in a few forms such as thermal, mechanical and electrical.

Electrical energy, measured in kWh, represents more than 30% of all used energy and it is on the rise. Part of electrical energy is used directly to produce heat or light (in electrolysis, metallurgical furnaces, industrial space heating, lighting, etc.).

The larger part of electrical energy is converted into mechanical energy in electric motors. Among electric motors, induction motors are most used both for home appliances and in various industries. This is so because they have been traditionally fed directly from the three phase a.c. electric power grid through electromagnetic power switches with adequate protection. It is so convenient.

Small power induction motors, in most home appliances, are fed from the local single phase a.c. power grids. Induction motors are rugged and have moderate costs, explaining their popularity.

In developed countries today there are more than 3 kW of electric motors per person, today and most of it is from induction motors. While most induction motors are still fed from three-phase or single-phase power grids, some are supplied through frequency changers (or power electronics converters) to provide variable speed. In developed countries, 10% of all induction motor power is converted in variable speed drives applications. The annual growth rate of variable speed drives has been 9% in the last decade while the electric motor markets showed an average annual growth rate of 4% in the same time.

Variable speed drives with induction motors are used in transportation, pumps, compressors, ventilators, machine tools, robotics, hybrid or electric vehicles, washing machines, etc.

The forecast is that, in the next decade, up to 50% of all electric motors will be fed through power electronics with induction motors covering 60 to 70% of these new markets.

1.1 Structural organization of shape

The basic difference between an induction motor and a synchronous AC motor with a permanent magnet rotor is that in the latter the rotating magnetic field of the stator will impose an electromagnetic torque on the magnetic field of the rotor causing it to move (about a shaft) and a steady rotation of the rotor is produced.

It is called synchronous because at steady state the speed of the rotor is the same as the speed of the rotating magnetic field in the stator.

By way of contrast, the induction motor does not have any permanent magnets on the rotor; instead, a current is induced in the rotor. To achieve this, stator windings are arranged around the rotor so that when energized with a poly phase supply they create a rotating magnetic field pattern which sweeps past the rotor. This changing magnetic field pattern induces current in the rotor conductors. These currents interact with the rotating magnetic field created by the stator and in effect cause a rotational motion on the rotor.

However, for these currents to be induced the speed of the physical rotor must be less than the speed of the rotating magnetic field in the stator (the synchronous frequency n_s) or else the magnetic field will not be moving relative to the rotor conductors and no currents will be induced. If by some chance this happens, the rotor typically slows slightly until a current is re-induced and then the rotor continues as before. This difference between the speed of the rotor and speed of the rotating magnetic field in the stator is called *slip*. It is unit less and is the ratio between the relative speed of the magnetic field as seen by the rotor (the slip speed) to the speed of the rotating stator field. Due to this, an induction motor is sometimes referred to as an asynchronous machine.

1.2 Induction motor

The largest motor: three-phase asynchronous motor 750W (25W second largest, followed synchronous motors from a CD player, and DC motor from a child's toy). Induction motor is a rotating electric machine (motor), operating on alternating current. It is the most widely used in electrical power at all.

Energy flow between the main components (stator and rotor) is implemented solely by electromagnetic induction, so the engine is often referred to as an induction motor.

The advantage of asynchronous motor is a high reliability, simple design and alternating current grid supply. Supply voltage can be single-phase or three phase. Three-phase one is significantly more used. Induction motor was invented by Nikola Tesla.

1.3 Constrution

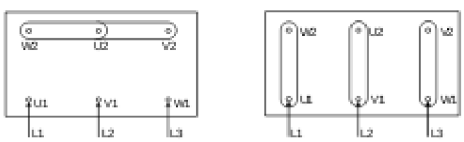


Figure 1: Terminal of an induction motor connected in star and delta(www.cs.wikipedia.org

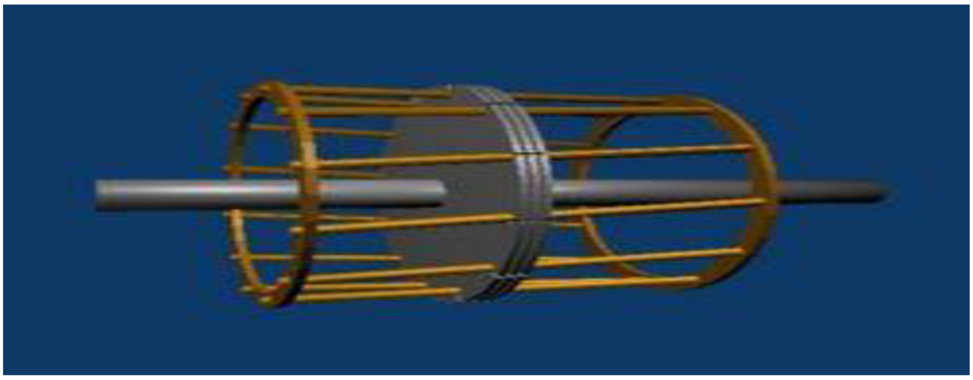


Figure 2: The squirrel-cage rotor of an induction motor(www.cs.wikipedia.org)

The induction machine is basically an a.c. polyphase machine connected to an a.c. power grid, either in the stator or in the rotor. The a.c. power source is, in general, three phase but it may also be single phase. In both cases the winding arrangement on the part of the machine–the primary–connected to the grid (the stator in general) should produce a traveling field in the machine airgap. This traveling field will induce voltages in conductors on the part of the machine not connected to the grid (the rotor, or the mover in general), - the secondary. If the windings on the secondary (rotor) are closed, a.c. currents occur in the rotor.

The interaction between the primary field and secondary currents produces torque from zero rotor speed onward. The rotor speed at which the rotor currents are zero is called the ideal no-load (or synchronous) speed. The rotor winding may be multiphase (wound rotors) or made of bars short circuited by end rings (cage rotors).

All primary and secondary windings are placed in uniform slots stamped into thin silicon steel sheets called laminations.

The induction machine has a rather uniform airgap of 0.2 to 3 mm. The largest values correspond to large power, 1 MW or more. The secondary windings may be short-circuited or connected to an external impedance or to a power source of variable voltage and frequency. In the latter case however the IM works as a synchronous machine as it is doubly fed and both stator and rotor-slip frequencies are imposed.

Though historically double stator and double rotor machines have also been proposed to produce variable speed more conveniently, they did not make it to the markets. Today's power electronics seem to move such solutions even further into oblivion.

In this chapter we discuss construction aspects and operation principles of induction machines. A classification is implicit. The main parts of any IM are

- The stator slotted magnetic core
- The stator electric winding
- The rotor slotted magnetic core

- The rotor electric winding
- The rotor shaft
- The stator frame with bearings
- The cooling system
- The terminal box

1.4 Starting of induction motors

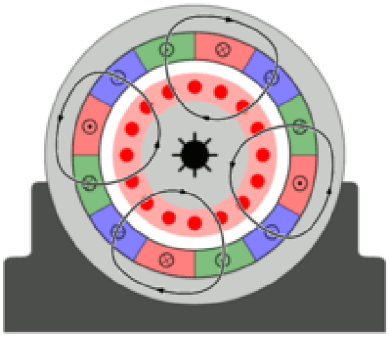


Figure 3: Rotating field formed by the stator is greater than the speed of the rotor (Ion Boldeia, 2002,page 10)

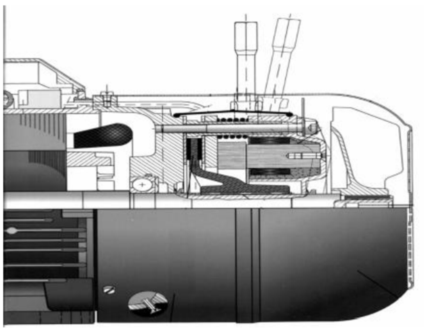


Figure 4: Induction motor with integrated electromagnetic brake Ion (Boldeia, 2002,page 20)

The cornerstone of an asynchronous motor is a rotating magnetic field created by passing an alternating three-phase stator windings. This magnetic field induces the rotor voltage and current resulting in a force rotating rotor. Speed n_s rotating field are given frequency voltage collected from the network and the number of poles three-phase motor.

$$n_s = \frac{60 \cdot f}{p} \quad [min^{-1}],$$

where f is frequency and p is the current number of stator pole pairs.

The rotor can never turn the same speed as the stator magnetic field. If so, then the rotor and the magnetic field to himself and did not move.

This would not induce stress and avoid the rotating force. The rate difference between field and rotor speed is called slip, expressed in percentage and defined as:

$$s = \frac{n_s - n}{n_s} \cdot 100 \quad [\%],$$

where n1 is the speed of stator magnetic field, n is the rotor speed. According to the slip value can be easily split the labor induction machines:

$s \in (-\infty, 0)$ – generator
$s \in (0, 1)$ – motor
$s \in (1, \infty)$ – breaking

1.4.Running

Figure 5:Types of anchors with a double cage(www.cs.wikipedia.org)

When starting an induction motor starting current up to 7 times higher than the nominal current. This creates a network large current surges in the relatively small starting torque. Therefore, direct start only allowed for motors of about 3kW. squirrel-cage motors..Reduce the high starting current for these types can be achieved only by reducing the motor starting voltage.

The most commonly used methods are: Stator starter - into a series of winding involving limiting resistors, which are gradually discarded during startup. To reduce heat loss in the resistance of the circuit are classified into the ballast coil, which, however, deteriorating factor in the network. This method is suitable for gentle traction engine that is loaded during start-up a little.

Starting Transformers - The trigger circuit connected transformers reduce the voltage acceleration and thus the starting current. For economic reasons, the most commonly used auto. At startup, the autotransformer can be overstressed, since immediately after the launching of the engine is disconnected from the network. This method of starting is used mainly for high power engines.

Switch star - triangle - Stator motor terminals are commonly connected in a triangle, if the start switch terminals to the star, the winding voltage decreases times the current consumption drops to third and performance. The method can be used only at low engine load. Solid state voltage regulator - is a modern procedure that can be achieved in a smooth engine start, power factor improvement and still save energy.

Anchors dual cages - one car is called the centrifugal and the other, located closer to the center, is called the runtime. Resistance cage - the cage made of material with higher resistivity.
Whirlpool anchor. Special winding grooves and bars are located around the perimeter of the rotor each of these wires has the same resistance, but different

- Stray inductances.

- Slip-ring motors.

Despite the brush collector rings are connected to the rotor rotor starter consists of three equal resistors, which are gradually phased out. At the end of the start winding is short circuited. The advantage is that engines can be loaded at start.

1.5 Speed control

Rotor speed:

$$n = n_1(1-s) = \frac{f_1}{p}(1-s),$$

Starting refers to speed, current, and torque variations in an induction motor when fed directly or indirectly from a rather constant voltage and frequency local power grid.

A "stiff" local power grid would mean rather constant voltage even with large starting currents in the induction motors with direct full-voltage starting (5.5 to 5.6 times rated current is expected at zero speed at steady state). Full-starting torque is produced in this case and starting over notable loads is possible.

A large design KVA in the local power grid, which means a large KVA power transformer, is required in this case. For starting under heavy loads, such a large design KVA power grid is mandatory.

On the other hand, for low load starting, less stiff local power grids are acceptable. Voltage decreases due to large starting currents will lead to a starting torque, which decreases with voltage squared. As many local power grids are less stiff, for low starting loads, it means to reduce the starting currents, although in most situations even larger starting torque reduction is inherent for cage rotor induction machines.

For wound-rotor induction machines, additional hardware connected to the rotor brushes may provide even larger starting torque while starting currents are reduced. In what follows, various starting methods and their characteristics are presented. Speed control means speed variation with given constant or variable load torque. Speed control can be performed by either open loop (feed Forward) or close loop (feedback). In this chapter, we will introduce the main methods for speed control and the corresponding steady state characteristics.

Transients related to starting and speed control are treated. Close loop speed control methods are beyond the scope of this book as they are fully covered by literature presented.

1.6 Braking

In plain disconnected from the network is in the engine (and possibly in other motor-driven devices (eg mobile)) accumulated a large kinetic energy, which has a long stop motors.

Braking torque needed to accelerate the engine to stop, you can create both mechanically and electronically.

Braking counter - changing the meaning of the stator rotating magnetic field creates a braking torque acting against the rotation of the rotor. Upon reaching zero speed, the engine must be disconnected, did not start to rotate in the opposite direction. All the kinetic energy is converted to heat, this method is very wasteful.

This method applicable only for very small capacity, meaning abrupt switching of the motor slip is created twice the size of the nominal motor frequency and thus there is huge congestion and increase engine power. This method is not really acceptable because all the heat generated remains in the engine braking, which is the heats.

Regenerative Braking - (see Electrodynamic brake occurs when the engine work as a generator, ie when n> n 1 can be used to stop the engine only if it is possible to change the frequency of rotating magnetic field drive. If it is possible to return the energy produced back to the network, it the most economical way of braking induction motor (the recovery). This method is used such modern locomotives, trams and trolleybuses. If the drive does not return generated electricity back into the network, they must be somewhere to burn, most frequent in the resistor. The second method uses the older locomotives , trams and trolleybuses. Both of these methods is advantageous that the energy produced is entrained out of the engine, which is unnecessary because it does not overheat. With this method we can to stop the motor to zero speed, maintained a constant braking torque, and the like.

Dynamic braking - (DC brake) stator winding is disconnected from the network and connects to the DC voltage source. The magnetic field of the stator is stationary and moving the rotor itself creates a braking torque. The size of the braking torque can be controlled by the size of the direct current only in a limited range. This method is very effective at higher speeds. And at speeds close to zero, the engine dobrzdit mechanically. (For the current four-pole induction motor is probably the most effective brake on the SS from 1Hz to 10Hz) This method of braking is very effective, potože all the heat generated remains in the engine braking, which is the heats.

1.7 Component

Stator - is composed of stator windings and double sheets. The main winding is 2/3 slots and auxiliary winding in the remaining 1/3. Rotor - always cage design.
A pure traveling stator mmf, with an open rotor winding and a constant airgap (slot opening effects are neglected), when the stator and iron core permeability is infinite, will produce a no-load ideal flux density in theair´gap as according to Biot – Savart law. This flux density will self-induce sinusoidal emfs in the stator windings.

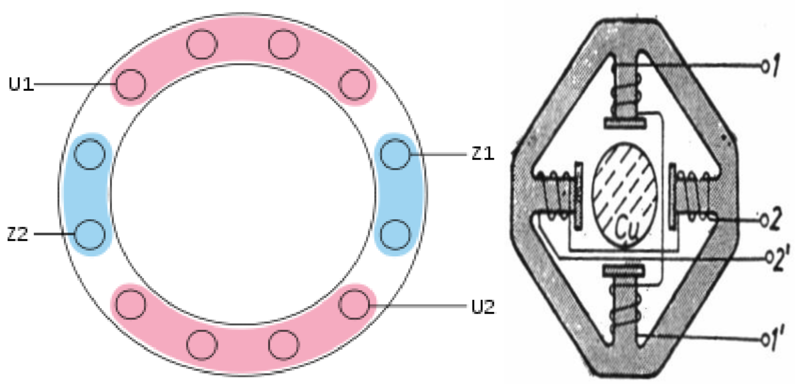


Figure 6: Ferrari's induction motor (Ion Boldeia, 2002,page 14)

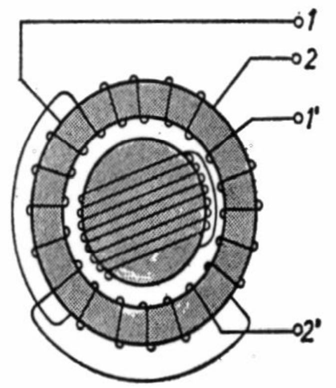


Figure 7:Tesla's induction motor (Ion Boldeia, 2002,page 14)

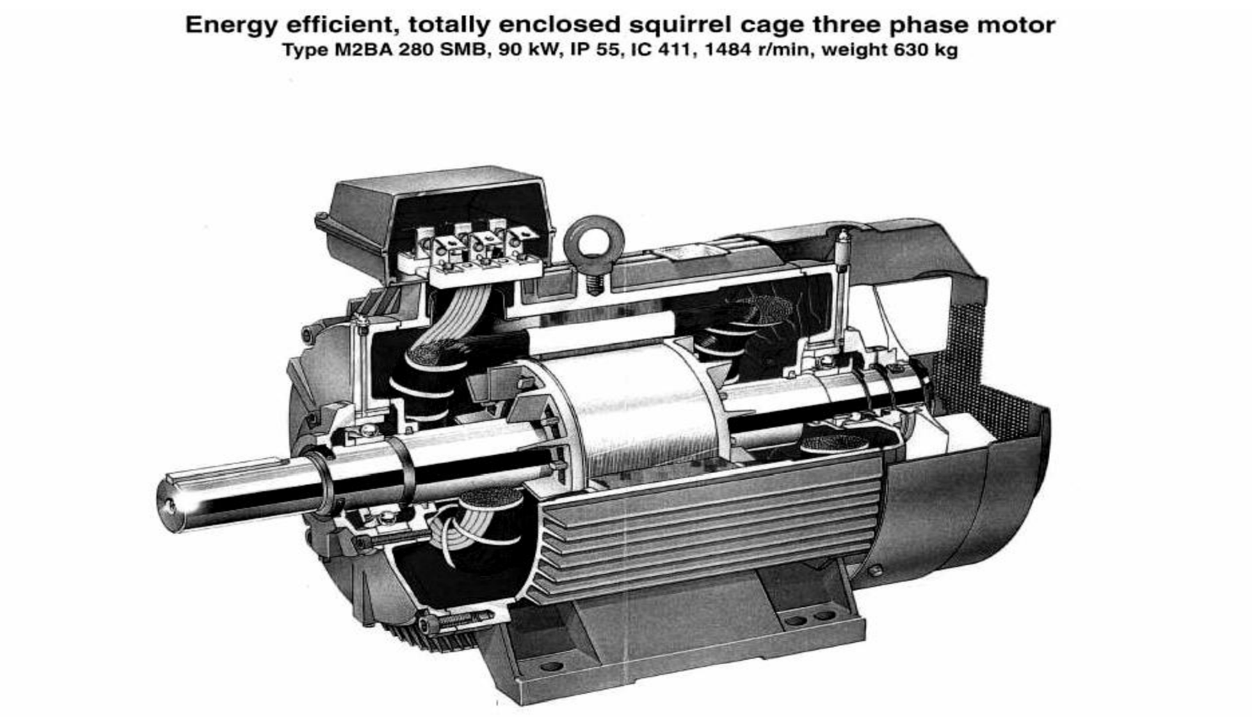


Figure 8:. A state-of-the-art three-phase induction motor (Ion Boldeia, 2002,page 14)

1.8 Principle of operation

To create the rotor torque, the magnetic field of the stator and the rotor to move. The single-phase power must be current in the main and auxiliary winding phase shift to create a rotating magnetic field. This is achieved by connecting a capacitor, active resistance or inductance increased auxiliary winding. The phase shift between the currents is 90 degrees. Effect of auxiliary winding is a single-engine must be running, so the start disconnect. The most common method of disconnecting the auxiliary winding is a centrifugal switch. It was found that if the auxiliary winding with a capacitor connected after starting the engine, increase torque by about 10% and improve the power factor.

1.9.Induction machines in applications

It is used to power small electric motors, some up to 2 kW, as in public networks is not appropriate or too technically permissible load phase. This type of motor is used primarily where it is necessary to regulate motor speed during operation as the drive compressors in refrigerators.

Speed n_s control using frequency inverters are not only increasingly expensive operation, but is also a source of unwanted electromagnetic interference. In normal domestic washing machines, lawn, fans, electric hand tools, food processors, vacuum cleaners, hair dryer for this very reason, is still far more prevalent classical commutator motors.

For devices with higher performance is necessary to use a combined three-phase voltage and the classic three-phase asynchronous motor.

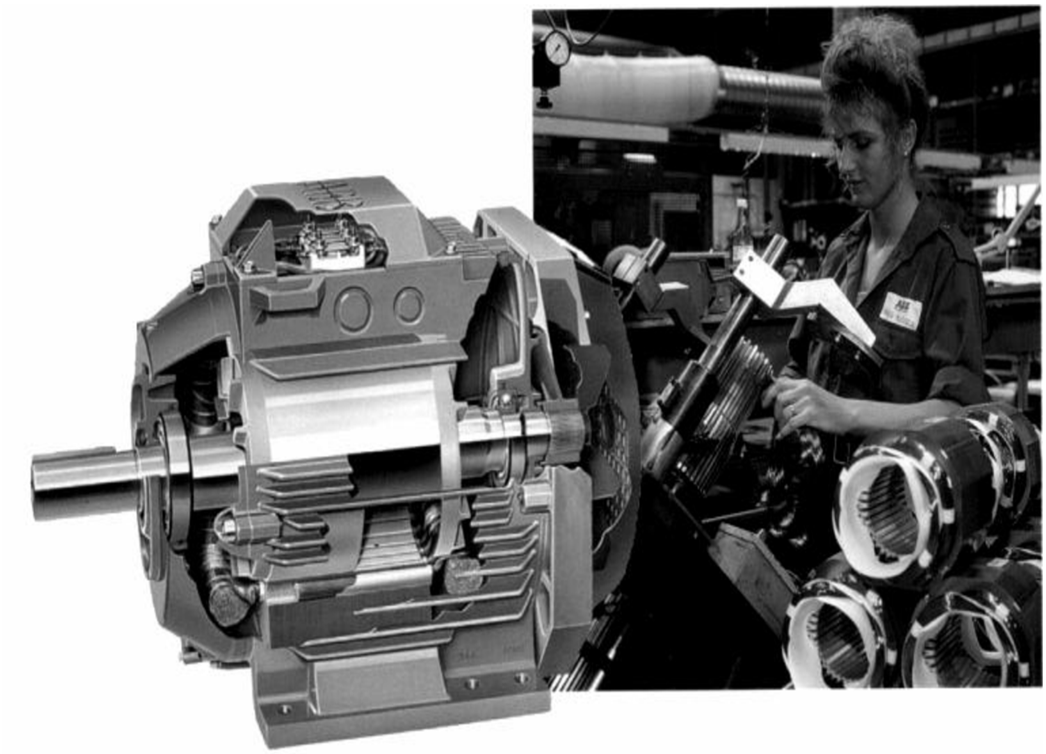


Figure 9:Aluminum frame induction motor ((Ion Boldeia, 2002,page 25)

Table 1: EU efficiency classes

Output [W]	2-pole Boradline		4-pole Boarline	
	EFF2/EFF3	EFF1/EFF2	EFF2/EFF3	EFF1/EFF2
1.1	76.2	82.8	76.2	83.8
1.5	78.5	84.1	78.5	85.0
2.2	81.0	85.6	81.0	86.0
3	82.6	86.7	82.6	87.4
4	84.2	87.6	84.2	88.3
5.5	85.7	88.6	85.7	89.2
7.5	87.0	89.5	87.0	90.1
11	88.4	90.5	88.4	91.0
15	89.4	91.3	89.4	91.8
18.5	90.0	91.8	90.0	92.2
22	91.4	92.9	90.5	92.6
30	92.0	93.3	91.4	93.2
37	92.5	93.7	92.0	93.6
45	93.0	94.0	92.5	93.9
55	93.6	94.0	93.0	94.2
75	93.6	94.6	93.6	94.7
90	93.9	95.0	93.9	95.0

2 . PERFORM ANALYSIS OF ONE PARTICULAR TYPE OF MACHINE

Table 2: Parameters of the motor

Motor values and frequency	340-460 V / 50Hz 400-520 V/ 60Hz
Output	600/ 720 W
Input	830/ (980) W +10%
Speed	2820 (3400) 1/min -3%
Current	1,45 (1,50) A +10%
Protection	IP56 (ČSN EN 60034-5)
Refrigeration	IC411(ČSN EN 60034-6)
Duty cycle	min 20 000 h, 12 years
Isolation class	F
Weight	cca 9,8 Kg

Table 3: Parameters in the idling

Parameters in the idling		
3*400 V, 50 Hz	3 * 460 V, 60 Hz	
Speed: min.	2980 1/min	3580 1/min
Input: max	200 W	200 W
Current: max.	1,0 A	0,9 A

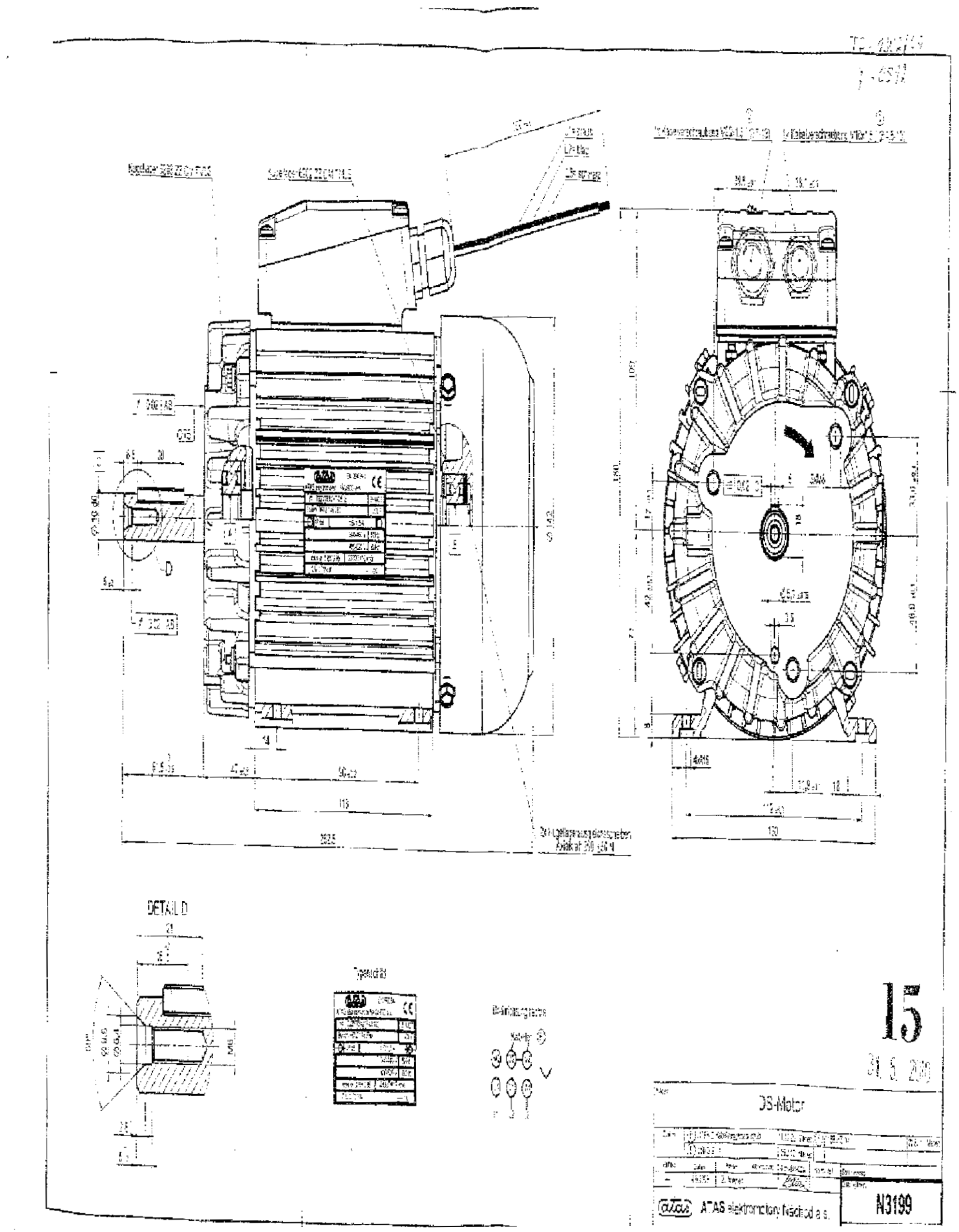


Figure 10:Schematic structure of three-phase asynchronous motor

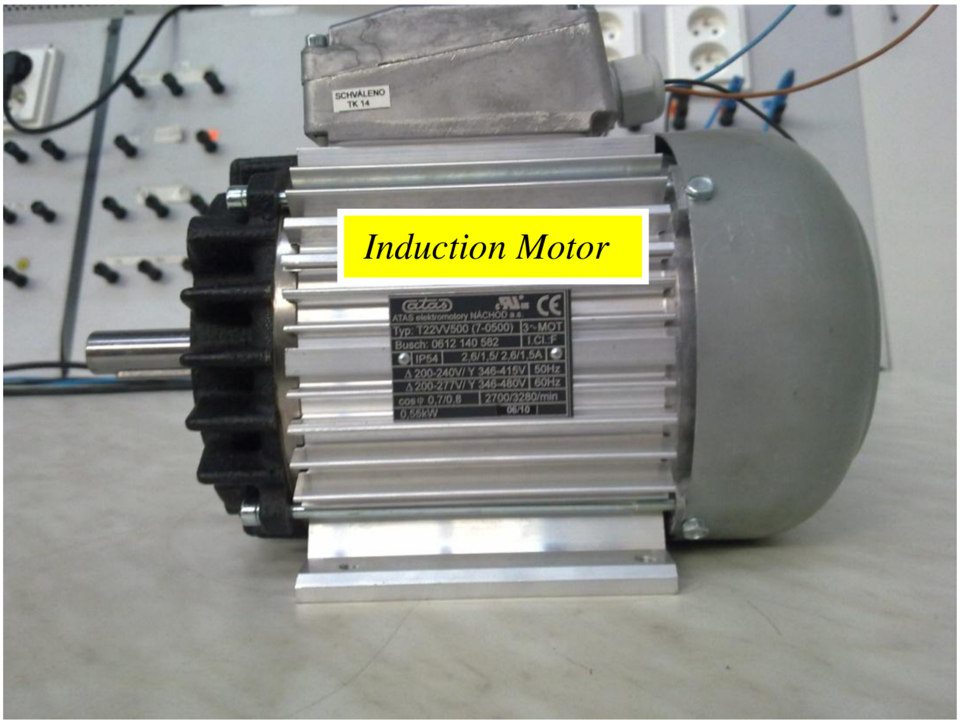


Figure 11:The induction motor used in analysis

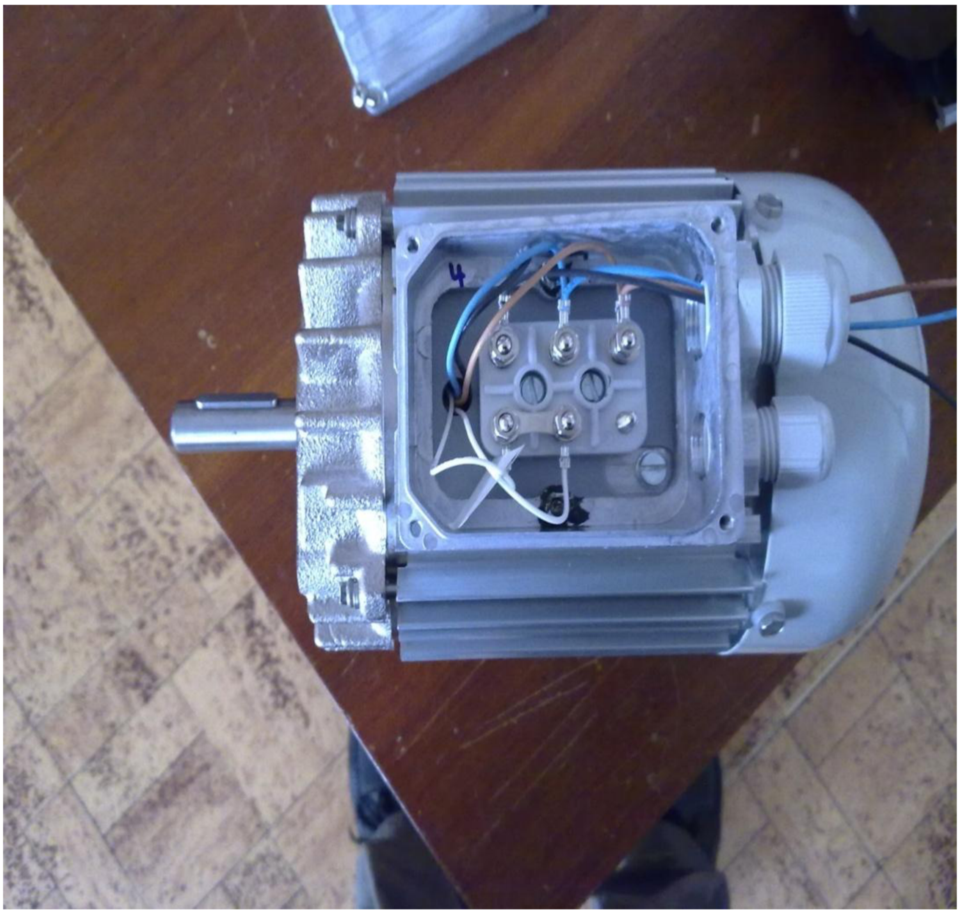


Figure 12:Induction motor connected in star and delta.

2.1 Measuring load

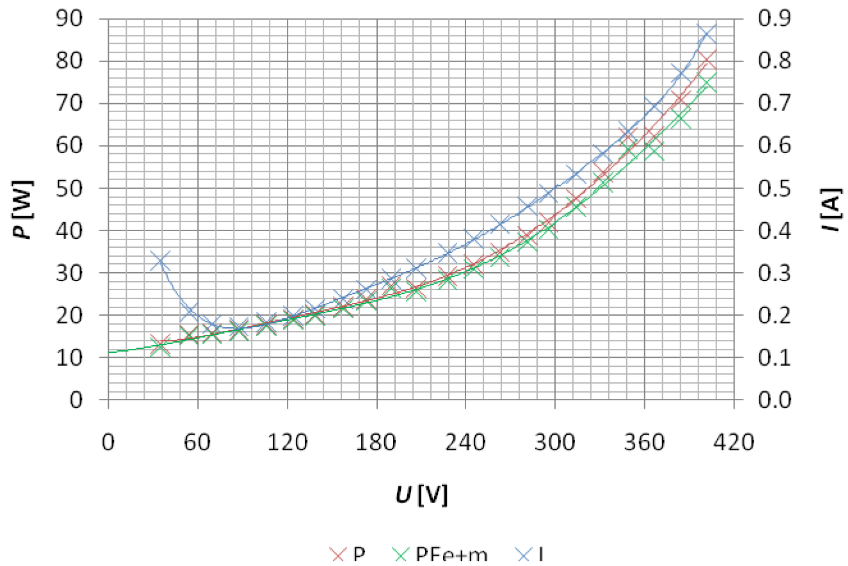
Load test is a test in which the machine operates as a motor shaft does no useful mechanical power, or in which the machine operates as a generator to find the open clamp.Measuring load both magnetic properties measured circuit machines, which expresses the characteristic magnetization (in practice is called the characteristic load), both no-load losses, depending on the voltage.

Load measurement is performed on an unloaded machine, either the electric machine is running as a generator or engine. In the former case, the zero electrical, mechanical performance in the second test machine. For machines that have their own field circuit, is usually measured load when running as a generator. In generator operation is difficult to determine the losses calibrated engine, electric dynamometer, etc., but it is not necessary network variable voltage and does not consider losses and losses in the windings due to current load as for the machine during the engine running. Measured at constant speed.

To test drive the machine in generator operation with sufficient engine power loss equal to the load voltage increased with the advance of 20 to 30% power to accelerate the machine at rated speed. Small medium sized machines can be advantageously used to drive an electric dynamometer, which measured both losses. Well suited Leonard DC motor drive circuit in the machine, for easy speed control. For low-speed alternator with a driver for oversized quick alarm can use to drive and own driver

Regulate If at a certain voltage, such as nominal, generating a synchronous motor so that power consumed by the smallest, so that the power factor equals one, so it will not set the value of field current practice differ from that which corresponds to this voltage according to load characteristics , measured in generator status. This circumstance allows to measure the characteristics of the motor load condition. This is necessary to have alternative current with voltage regulation in a wide range.

Division of mechanical load losses from the losses in iron



2.2 Measurement of short

Test cage (synchronous machine) test in which the machine operates as a generator terminals connected short-cage measurements, we find dispersion relations machine and measure the characteristic short, the size of losses short and AC motor and the size of breakaway torque. The values determined by measuring the short circuit determining characteristic values for the other machines in the normal operation or fault. Thus the transformer can be determined from measurements of short-and impedance voltage drop under load transformers, asynchronous

motors with squirrel-cage and synchronous motors the size of breakaway torque point short for the construction of a circular diagram, with some reactance of synchronous machines, the size of steady short circuit current (short circuit current) etc.

Measurements carried out for short, separately excited machines in machine operation and constant-speed and short-circuit armature windings (in DC machines) or the stator (for synchronous machines). For machines that do not own field circuit, is measured briefly stalled the machine, or at very low speeds, the engine is measured, as well as the measurement of transformer short-circuit, the secondary winding short circuited. The synchronous motors of self-start is measured as the short-stalled machine, the machine is running at rated speed. The excitation current or voltage test equipment should be managed so that current machines remained the order of the nominal value of the current In. Measurement is performed briefly in a warm machine, particularly preferably after warming the test. It should be distinguished from the measurement of short-short-circuit test machines, which usually takes place at a alternator and transformers for the operation with full voltage sudden connection to the circuit so that the short circuit current reaches a multiple of rated current machine.

The purpose of the short circuit test is checking the mechanical strength of winding frames, shaft and base of the machine.The sudden short circuit test IEC 60034-3 standard specifies that the machine must be designed so that during operation with rated load and 1.05 times rated voltage stayed at their terminals without any kind of short circuit faults, provided that the maximum phase current is limited external means to a value exceeding the maximum phase current progress in the three-phase short circuit. Short circuit must be maintained for at least 3 seconds "without fault" means that the machine may be damaged so that it caused his removal from service, even though there may be some deformation of the stator windings.

2.3 Characteristics of short

Characteristic short on machines with a separate excitation circuit (AC and synchronous machine) the dependence of short circuit current Ik, the excitation current: Ik = f (Ib). For machines without a separate excitation circuit (induction machines and transformers) is a short-circuit current dependence on supply voltage Ik: Ik = f (Uk). The course features short is a straight line if the circuit impedance measured standing still. For synchronous machines, while yielding the characteristic short, depending on the excitation current, but not here does not apply due to the curvature of the characteristics of short linear features in vain, because the measurement of short-machine works with a small magnetic flux. In addition, quantification of the value of the characteristic short give, for the unsaturated state. Circuit impedance remains constant only at lower current machines. For larger currents are set in the shape of their heads and teeth saturation scattering paths. It manifests itself on machines with more carbonated polozavřenými and closed grooves, especially on induction motors with squirrel cage. Then saturation is reduced and the circuit impedance characteristics is rising against the linear the steeper. In short, you can specify the characteristics of some important values, which vary depending on the type of machine.

2.4 Load losses

Load losses, which are also called shock loss, measured on machines with a separate excitation circuit based on current machines, the machines without a separate excitation circuit (inductive and transformer), depending on supply voltage. Output short circuit in the form of winding losses

(Joule losses) and any additional loss. For machines on which it is measured during operation (DC and synchronous), they also come into the mechanical losses. Losses in the iron saturation due to the small machines are small and yet commonly ignored. Losses have a short course depending on the current approximately parabolic. For machines that are trying in the short run, based on characteristics of the time on the vertical axis, whose remoteness from the beginning is equal to a constant mechanical losses.

The losses may be short for transformers and synchronous machines to calculate the additional losses by its own losses, subtract losses short in the winding, for calculating the size of the Machine and the winding resistance at a temperature corresponding to the winding temperature measurement. These losses translated to operating temperature with respect to the winding losses increase with temperature, while the additional losses with decreasing temperature. In measuring the values of the measurements must have a short account of the winding temperature rise during tests, which can grow very quickly, because the current machines are quite substantial and when measured on the machine at rest is a small cooling machine. Time constant warming coil in a modern, well-cooled alternators and dry transformers are short (10-20 minutes). Changing the resistance windings warming may slightly affect the characteristic short; much more is characteristic losses short and mainly the size of breakaway torque.

As a short measure of self-generating machines without usually at reduced voltages, the measured value converted to the nominal voltage Un. This conversion is simple, rode the course feature a short straight line, because then converted currents in voltage ratio and the ratio of moments dvojmocí tension. However, if the course features a short straight line, is converting those variables more difficult.

2.5 Characteristic load

Characteristics of load (magnetization curve) determines the dependence of the internal induced voltage (the value of the internal induced voltage is equal to the negative value of electromotive force) on the excitation current Internal induced voltage at constant machine speed or constant network frequency proportional to the magnetic flux or magnetic induction machine.

The excitation current is proportional to the excitation maagnet power, or intensity of magnetic field. It will therefore be idle characteristics U0 = f (Ib) to the same scale as the dependence B = f (h) of the magnetizing circuit and its progress will depend on the properties used magnetic material.

When measuring the characteristics of the load on the machine running the machine as a generator of the Gentiles an auxiliary electric motor or a calibrated dynamometer, we also measured the loss. We maintain a constant speed and changing the excitation current and the size of the induced voltage of the machine from top to bottom, ie from the voltage.

When measuring the characteristics of the load on the machine running as a motor, is fed to the machine terminal voltages of variable size from U0 = 1.25 to 0.25 Un Un and maintain a constant speed again. The AC machine is taken standing voltage variable frequency, such as induction of the regulator or alternator. Current is measured in all three phases and the arithmetic mean of the measured values is taken. The voltage measured at the terminals of all types of electric motors is greater than the internal induced voltage of the losses caused by the shock load resistance and leakage reactance powered winding.. Therefore, directly yields the terminal voltage dependence of the magnetization U0 (excitation) current I_0.

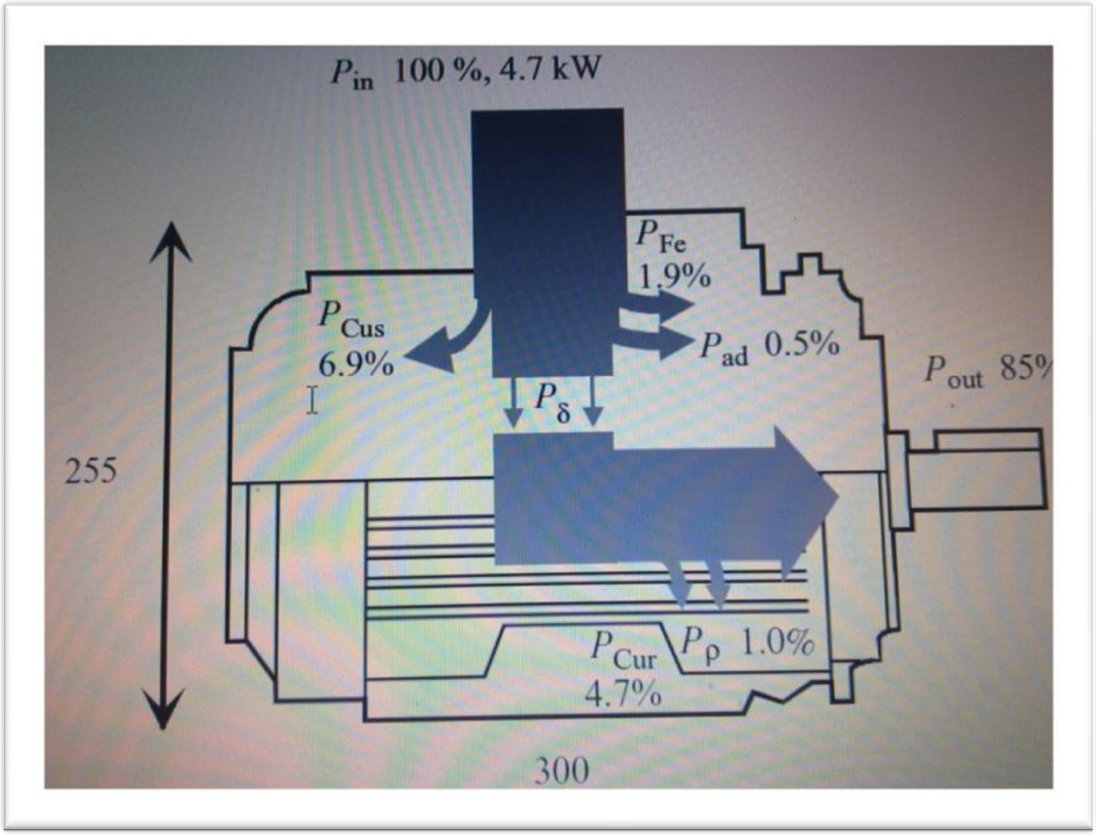


Figure 13:. Sankey diagram of a 4 kW two-pole induction motor(Juha Pyrhonen,2008, page 479)

.

P_{Fe}, iron losses; P_{Cus}, resistive losses of the stator; P_{ad}, additional losses; P_{δ}, air-gap power; P_{Cur}, resistive losses of the rotor; P_{ρ}, friction losses. The losses (700W in total) have to be removed from the machine at an acceptable temperature difference to the ambient.

3 DESIGN OPTIONS INCREASE EFFICIENCY, PROVIDE EVIDENCE OF BASIC CALCULATIONS

Active power is:

$$P_\delta = M\omega_1 = M \times 2\pi \frac{f}{p} = M \times 2 \times \pi \times n_1 = P_{1n} - P_{1n} - \left(\Delta P_{j1} + \Delta P_{Fe} \right) = \quad [W]$$

Mechanical power is:

$$P_{mech} = M * \omega = M * \omega * (1 - s) = \qquad [W]$$

Electrical power is:

$$P_{el} = P_\delta - P_{mech} = M(\omega_1 - \omega) \qquad [W]$$

Where P_{el} is electric power, which consumes all the active resistance of the rotor. In the event that the rotor ring motor starter is engaged, is included in the value of P_{el} and resistance of the triggers.

$$\frac{P_{el}}{P_\delta} = M * \frac{\omega_1 - \omega}{M\omega_1} = s \qquad [-]$$

$$P_{el} = P_\delta * s \qquad [W]$$

Electric power P_{el} is called slip. As we shall see later, you can change it slip performance speed control of induction motor. The machines get the shaft mechanical power P_{mech}, the engine produces, but the power P2, less mechanical losses on their own machines and Δ P_{mech} additional loss of ΔP_d

$$P_2 = P_{mech} - \Delta P_{mech=} = \Delta P_d \qquad [W]$$

Size performance P_{mech} determine relatively easily from the circuit model and is equal to the active power consumed by the resistor

$$\frac{R_2^{'}}{s} = (1 - s)$$

$$P_{mech} = m_1 * I_2^{'2} * (1 - s) \qquad [W]$$

Where m_1 is the number of machine phases. The mechanical torque is:

$$M_{mech} = \frac{P_{mech}}{\omega} \qquad [N.m]$$

Angular rotor speed is equal to the difference in angular velocity of rotating stator field (ω_1) and rotor (ω_2).

$$\omega = (\omega_1 - \omega_2) = \omega_1(1 - s) \qquad [rad/s]$$

$$\omega_1 = 2\pi * \frac{f_1}{p}$$

The current value is

$$I_2^{\prime} = \frac{U_1}{\sqrt{(R_1 + \frac{R_2^{\prime}}{s})^2 + (X_{r1} + X_{r20}^{\prime})^2}} \qquad [A]$$

Substituting the relation we obtain an equation for the mechanical torque:

$$M_{mech} = \frac{U_1^2 * m_1 * p\frac{R_2^{\prime}}{s}}{2\pi * f_1 * [(R_1 + \frac{R_2^{\prime}}{s})^2 + (X_{r1} + X_{r20}^{\prime})^2]} \qquad [N.m]$$

This equation expresses the dependence M = f (s), which plotted graphically represents the torque characteristics of induction machine (Fig.14).

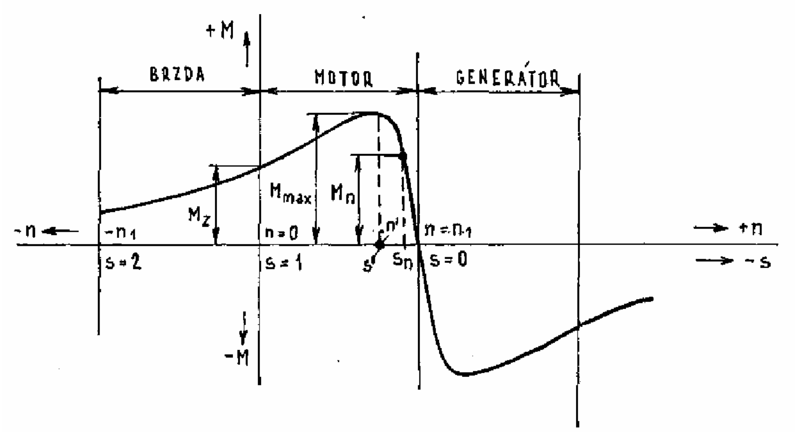


Figure 14:Torque characteristics of induction machine

At the rated engine load generates mechanical torque on slip n Mn and its corresponding time nn.V speed motor connection to a network is n = 1 = 0 and develops motor starting torque Mz, which determine the relationship by substituting for s = 1.

$$M_z = \frac{U_1^2 * m_1 * pR_2^{\prime}}{2\pi * f_1 * [(R_1 + \frac{R_2^{\prime}}{s})^2 + (X_{r1} + X_{r20}^{\prime})^2]} \qquad [N.m]$$

The engine develops a maximum speed at some point, which we determine by calculating the maximum torque characteristics. slippage also identify with the 'corresponding to the maximum moment Mmax.

$$s' = \frac{R_2'}{\sqrt{(R_1)^2 + (X_{r1} + X_{r20}')^2}} \qquad [-]$$

$$M_{max} = \frac{U_1^2 * m_1 * p}{4\pi * f_1 * [R_1 + \sqrt{(R_1)^2 + (X_{r1} + X_{r20}')^2}]} \qquad [N.m]$$

where,

V1 = Stator Terminal Voltage
I1 = Stator Current
R1 = Stator Effective Resistance
X1 = Stator Leakage Reactance
Z1 = Stator Impedance (R1 + jX1)
IX = Exciting Current (this is comprised of the core loss component = Ig, and a magnetizing current = Ib)
E2 = Counter EMF (generated by the air gap flux)
R=2.4 [Ω]
P400=80.4[W]
P_{cu}=5.382653[W]
P_{mech}=14 [W]
P_{fe}=61.0173 [W]

Table 4:Measurement of no load

MERENI	URMS,1	IRMS,1	LAMBDA,1	P,1	Q,1	S,1	URMS,2	IRMS,2
1	229.800	0.849	0.107	20.960	194.010	195.140	231.670	0.854
2	219.820	0.763	0.109	18.280	166.790	167.790	221.930	0.758
3	209.740	0.686	0.122	17.590	142.680	143.760	211.460	0.686
4	199.750	0.619	0.139	17.210	122.420	123.620	201.010	0.630
5	189.680	0.571	0.145	15.660	107.120	108.260	191.830	0.579
6	179.910	0.522	0.144	13.510	92.840	93.820	181.210	0.530
7	169.600	0.477	0.153	12.390	79.850	80.810	170.750	0.487
8	161.680	0.446	0.158	11.390	71.270	72.170	162.540	0.456
9	150.700	0.410	0.163	10.070	60.880	61.710	151.600	0.409
10	140.680	0.374	0.183	9.630	51.710	52.600	141.630	0.379
11	130.540	0.341	0.202	8.990	43.570	44.490	131.560	0.348
12	118.900	0.308	0.225	8.230	35.730	36.660	119.020	0.309
13	109.380	0.286	0.292	9.150	29.950	31.320	109.970	0.288
14	109.450	0.287	0.290	9.110	30.080	31.430	109.900	0.288
15	99.910	0.260	0.296	7.690	24.840	26.000	99.860	0.259
16	91.180	0.242	0.334	7.360	20.760	22.020	90.880	0.236
17	80.000	0.215	0.401	6.880	15.750	17.190	80.000	0.217
18	71.950	0.202	0.454	6.610	12.970	14.560	71.730	0.200
19	61.110	0.182	0.541	6.010	9.350	11.120	61.540	0.187
20	50.360	0.173	0.651	5.680	6.630	8.730	50.680	0.178
21	40.570	0.187	0.749	5.680	5.030	7.590	40.170	0.179
22	31.190	0.211	0.807	5.310	3.890	6.580	31.330	0.211
23	20.007	0.336	0.689	4.630	4.875	6.724	20.425	0.335

LAMBDA,2	P,2	Q,2	S,2	URMS,3	IRMS,3	LAMBDA,3	P,3
0.159	31.500	195.270	197.800	233.960	0.891	0.134	27.910
0.162	27.280	165.910	168.140	224.180	0.796	0.141	25.220
0.160	23.260	143.090	144.970	213.120	0.708	0.141	21.320
0.191	24.140	124.260	126.590	202.970	0.653	0.156	20.720
0.186	20.640	109.210	111.150	193.140	0.595	0.153	17.520
0.190	18.280	94.290	96.050	182.580	0.548	0.158	15.780
0.192	15.990	81.640	83.190	171.520	0.500	0.159	13.670
0.198	14.620	72.590	74.050	163.320	0.469	0.167	12.770
0.205	12.730	60.690	62.010	152.600	0.426	0.185	12.040
0.218	11.690	52.400	53.690	142.150	0.390	0.192	10.630
0.233	10.640	44.460	45.720	131.940	0.355	0.205	9.590
0.247	9.070	35.620	36.760	119.440	0.316	0.239	9.040
0.283	8.970	30.420	31.720	109.480	0.286	0.283	8.870
0.278	8.780	30.390	31.630	109.500	0.285	0.284	8.840
0.307	7.930	24.570	25.820	100.080	0.264	0.311	8.210
0.327	7.030	20.300	21.480	90.860	0.239	0.351	7.610
0.384	6.680	16.040	17.370	79.950	0.213	0.390	6.650
0.427	6.110	12.970	14.340	71.600	0.196	0.454	6.380
0.522	5.990	9.800	11.480	61.310	0.181	0.516	5.730
0.616	5.570	7.130	9.040	50.330	0.169	0.619	5.280
0.696	5.000	5.170	7.190	39.470	0.172	0.753	5.120
0.779	5.140	4.140	6.600	31.030	0.204	0.797	5.040
0.649	4.435	5.201	6.835	19.756	0.317	0.674	4.227

Q,3	S,3	P,SIGMA	Q,SIGMA	S,SIGMA	rpm
206.560	208.440	80.370	595.840	601.370	2997.000
176.750	178.540	70.780	509.460	514.470	2996.000
149.370	150.890	62.170	435.150	439.620	2996.000
130.870	132.500	62.070	377.550	382.710	2996.000
113.550	114.900	53.830	329.890	334.310	2995.000
98.830	100.080	47.570	285.960	289.950	2994.000
84.700	85.800	42.050	246.190	249.790	2994.000
75.550	76.620	38.780	219.410	222.840	2993.000
63.940	65.060	34.850	185.500	188.780	2994.000
54.380	55.410	31.950	158.500	161.710	2992.000
45.820	46.820	29.220	133.860	137.020	2991.000
36.700	37.790	26.340	108.050	111.220	2989.000
30.020	31.300	27.000	90.390	94.340	2987.000
29.920	31.200	26.740	90.390	94.260	2987.000
25.080	26.390	23.830	74.480	78.200	2984.000
20.320	21.700	22.000	61.380	65.210	2981.000
15.680	17.040	20.210	47.470	51.590	2978.000
12.520	14.050	19.100	38.450	42.940	2972.000
9.510	11.100	17.730	28.660	33.700	2962.000
6.690	8.520	16.530	20.450	26.300	2945.000
4.470	6.800	15.810	14.670	21.580	2910.000
3.820	6.330	15.490	11.850	19.510	2833.000
4.631	6.270	13.292	14.707	19.829	2198.000

Table 5:Processing of measured values

U (V)			I (A)	$\frac{I}{3}$	P (W)
401.507	695.430	231.810	2.594	0.865	80.370
384.475	665.930	221.977	2.317	0.772	70.780
366.225	634.320	211.440	2.079	0.693	62.170
348.564	603.730	201.243	1.901	0.634	62.070
331.774	574.650	191.550	1.745	0.582	53.820
313.905	543.700	181.233	1.600	0.533	47.570
295.528	511.870	170.623	1.464	0.488	42.050
281.481	487.540	162.513	1.371	0.457	38.780
262.637	454.900	151.633	1.245	0.415	34.840
245.062	424.460	141.487	1.143	0.381	31.950
227.499	394.040	131.347	1.043	0.348	29.220
206.322	357.360	119.120	0.934	0.311	26.340
189.850	328.830	109.610	0.861	0.287	26.990
189.862	328.850	109.617	0.860	0.287	26.730
173.118	299.850	99.950	0.782	0.261	23.830
157.570	272.920	90.973	0.717	0.239	22.000
138.535	239.950	79.983	0.645	0.215	20.210
124.292	215.280	71.760	0.598	0.199	19.100
106.209	183.960	61.320	0.550	0.183	17.730
87.394	151.370	50.457	0.521	0.174	16.530
69.403	120.210	40.070	0.538	0.179	15.800
54.011	93.550	31.183	0.626	0.209	15.490
34.750	60.188	20.063	0.988	0.329	13.292

To determine the mean value of voltage, current and power according the measurment:

To determine the mean value of voltage:

$$U=\frac{1}{\sqrt{3}}(U_{RMS1}+U_{RMS2}+U_{RMS3})=\frac{1}{\sqrt{3}}(229.8+231.67+233.96)=401.50\ [V]$$

To determine the mean value of current:

$$I=(I_{RMS1}+I_{RMS2}+I_{RMS3})=0.849+0.854+0.891=2.594\ [A]$$

To determine true power engine idling:

$$P=(P_1+P_2+P_3)=(20.96+31.5+27.91)=80.37\ [W]$$

Losses in the windings

$$P_j=3*I^2*R$$

Losses in iron:

$$P_{fe}=P-Pj$$

Factor in the idling:

$$Cos\varphi=P_{1N}/(\sqrt{3}\ \ U*\ I\ )$$

Slippage:

$$S[\%]=(n_s-n_n)*100/ns$$

Table 6:Extrapoled values, summary of characteristics

U [V]	I[A]	P[W]	R[Ω]	Pj=3*I^2*R	Pfe=P-Pj	Cosφ=P1N/(√3 U* I)	n_s	n_n	S[%]=(ns-nn)*100/ns
401.507	0.865	80.370	2.4	5.382653768	74.987	0.13366219	3000	2997.000	0.1
384.475	0.772	70.780	2.4	4.295903432	66.484	0.137600804	3000	2996.000	0.133333333
366.225	0.693	62.170	2.4	3.458125448	58.712	0.141422444	3000	2996.000	0.133333333
348.564	0.634	62.070	2.4	2.892257568	59.178	0.16221341	3000	2996.000	0.133333333
331.774	0.582	53.820	2.4	2.436299208	51.384	0.161005688	3000	2995.000	0.166666667
313.905	0.533	47.570	2.4	2.047488032	45.523	0.164070077	3000	2994.000	0.2
295.528	0.488	42.050	2.4	1.714402568	40.336	0.168351181	3000	2994.000	0.2
281.481	0.457	38.780	2.4	1.503932168	37.276	0.174040241	3000	2993.000	0.233333333
262.637	0.415	34.840	2.4	1.239820808	33.600	0.184564851	3000	2994.000	0.2
245.062	0.381	31.950	2.4	1.044793472	30.905	0.19759917	3000	2992.000	0.266666667
227.499	0.348	29.220	2.4	0.870446088	28.350	0.213272672	3000	2991.000	0.3
206.322	0.311	26.340	2.4	0.697436552	25.643	0.236822918	3000	2989.000	0.366666667
189.850	0.287	26.990	2.4	0.592505888	26.397	0.286122074	3000	2987.000	0.433333333
189.862	0.287	26.730	2.4	0.591542408	26.138	0.28357923	3000	2987.000	0.433333333
173.118	0.261	23.830	2.4	0.489719808	23.340	0.304728029	3000	2984.000	0.533333333
157.570	0.239	22.000	2.4	0.411156488	21.589	0.337326137	3000	2981.000	0.633333333
138.535	0.215	20.210	2.4	0.33282	19.877	0.391748281	3000	2978.000	0.733333333
124.292	0.199	19.100	2.4	0.286466048	18.814	0.444794443	3000	2972.000	0.933333333
106.209	0.183	17.730	2.4	0.241648128	17.488	0.52608978	3000	2962.000	1.266666667
87.394	0.174	16.530	2.4	0.217319552	16.313	0.628564559	3000	2945.000	1.833333333
69.403	0.179	15.800	2.4	0.231813512	15.568	0.732509674	3000	2910.000	3
54.011	0.209	15.490	2.4	0.3130002	15.177	0.79414822	3000	2833.000	5.566666667
34.750	0.329	13.292	2.4	0.781073288	12.511	0.670503078	3000	2198.000	26.73333333

1.4. Extrapoled values, summary of characterists, load measurement result

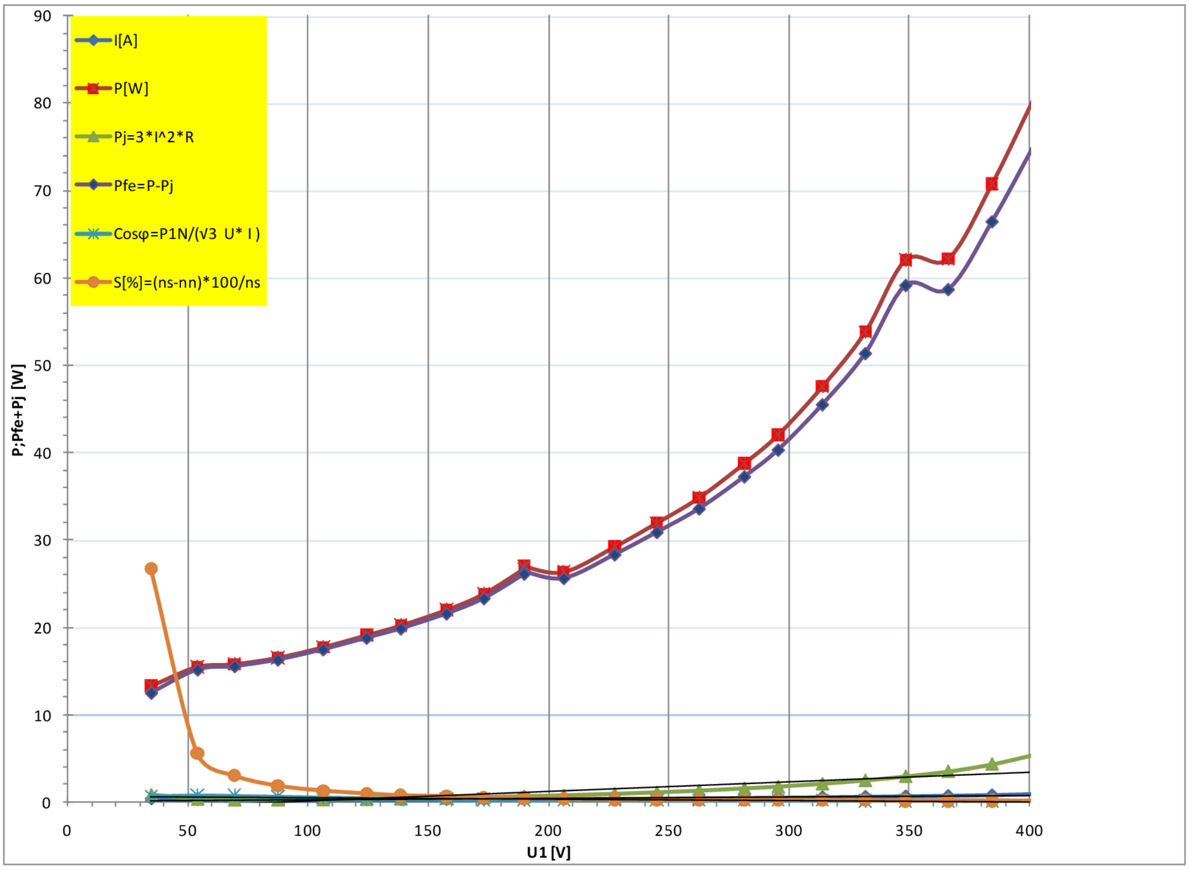


Table 7:Measuring load

MERENI	URMS,1	IRMS,1	LAMBDA,1	P,1	Q,1	S,1	URMS,2	IRMS,2	LAMBDA,2	P,2	Q,2	S,2
1	228.800	2.206	0.889	448.500	231.600	504.700	231.390	2.213	0.886	453.300	237.900	512.000
2	228.330	2.065	0.883	416.400	221.000	471.400	231.240	2.078	0.882	423.600	226.600	480.400
3	228.760	1.937	0.876	388.200	213.500	443.100	231.340	1.954	0.875	395.400	218.900	451.900
4	228.260	1.811	0.866	358.100	206.600	413.400	231.210	1.828	0.868	367.000	209.700	422.700
5	228.540	1.684	0.853	328.300	200.900	384.800	231.300	1.703	0.856	337.300	203.400	393.900
6	228.590	1.569	0.837	300.300	196.000	358.600	231.430	1.590	0.844	310.400	197.600	368.000
7	228.290	1.459	0.821	273.330	190.300	333.050	231.160	1.487	0.828	284.710	192.680	343.780
8	228.740	1.359	0.799	248.410	186.820	310.820	231.480	1.395	0.808	260.770	190.410	322.890
9	229.010	1.268	0.768	223.110	185.870	290.390	231.430	1.295	0.780	233.700	187.770	299.790
10	229.070	1.189	0.731	198.960	185.840	272.250	231.760	1.208	0.750	209.900	185.190	279.920
11	229.310	1.112	0.684	174.450	186.030	255.030	232.230	1.124	0.709	184.960	184.200	261.030
12	229.440	1.033	0.634	150.330	183.210	236.990	232.350	1.062	0.664	163.830	184.430	246.680
13	229.240	0.975	0.565	126.360	184.360	223.510	232.300	0.993	0.608	140.270	183.020	230.590
14	229.360	0.926	0.489	103.880	185.120	212.280	232.490	0.942	0.540	118.250	184.190	218.880
15	228.980	0.888	0.403	81.990	186.030	203.290	232.200	0.893	0.461	95.530	184.060	207.370
16	229.410	0.863	0.303	59.920	188.600	197.890	232.640	0.865	0.366	73.580	187.330	201.260
17	228.980	0.846	0.206	39.950	189.460	193.630	232.310	0.843	0.270	52.890	188.650	195.920
18	229.890	0.843	0.100	19.370	192.800	193.780	232.840	0.845	0.162	31.860	194.110	196.710

URMS,3	IRMS,3	LAMBDA,3	P,3	Q,3	S,3	P,SIGMA	Q,SIGMA	S,SIGMA	M[N.m]	rpm
234.990	2.197	0.886	457.600	238.900	516.200	1359.400	708.400	1532.900	3.400	2670.000
234.810	2.066	0.880	427.100	230.100	485.100	1267.100	677.700	1436.900	3.200	2704.000
234.770	1.942	0.873	398.100	222.100	455.800	1181.600	654.500	1350.800	3.000	221.000
234.820	1.826	0.864	370.300	216.200	428.800	1095.500	632.500	1265.000	2.800	2745.000
234.880	1.703	0.850	340.200	210.500	400.000	1005.800	614.700	1178.800	2.600	2769.000
234.990	1.595	0.835	313.000	206.300	374.900	923.700	600.000	1101.500	2.400	2792.000
234.250	1.493	0.817	285.580	201.900	349.740	843.620	584.880	1026.570	2.200	2814.000
234.260	1.398	0.793	259.600	199.510	327.410	768.780	576.740	961.120	2.000	2835.000
234.520	1.301	0.765	233.540	196.520	305.220	690.360	570.160	895.410	1.800	2854.000
235.000	1.227	0.732	211.180	196.360	288.360	620.040	567.390	840.530	1.600	2872.000
235.330	1.150	0.690	186.690	195.940	270.640	546.100	566.170	786.710	1.400	2892.000
234.820	1.085	0.635	161.790	196.770	254.740	475.950	564.400	738.420	1.200	2908.000
235.210	1.029	0.577	139.640	197.770	242.100	406.270	565.150	696.200	1.000	2924.000
235.270	0.981	0.505	116.660	199.240	230.890	338.790	568.550	662.040	0.800	2941.000
235.090	0.938	0.429	94.550	199.270	220.560	272.070	569.350	631.230	0.600	2956.000
235.420	0.913	0.333	71.620	202.550	214.840	205.120	578.480	613.990	0.400	2970.000
235.090	0.891	0.240	50.320	203.340	209.470	143.160	581.450	599.020	0.200	2983.000
235.230	0.889	0.132	27.630	207.380	209.210	78.860	594.290	599.690	0.000	2998.000

Table 8:Short measurement

MERENI	URMS,1	IRMS,1	LAMBDA,1	P,1	Q,1	S,1	URMS,2	IRMS,2	LAMBDA,2	P,2	Q,2	S,2
1	20.285	0.460	0.522	4.866	7.954	9.325	20.146	0.456	0.474	4.356	8.095	9.193
2	30.621	0.777	0.577	13.723	19.448	23.802	30.344	0.763	0.533	12.321	19.583	23.137
3	40.842	1.103	0.603	27.170	35.920	45.040	40.997	1.089	0.570	25.420	36.691	44.637
4	52.187	1.464	0.627	47.910	59.530	76.410	52.444	1.446	0.591	44.800	61.200	75.850
5	61.713	1.780	0.642	70.520	84.220	109.850	62.035	1.752	0.609	66.160	86.250	108.700
6	70.900	2.081	0.657	97.000	111.220	147.580	71.680	2.064	0.623	92.220	115.700	147.960
7	79.960	2.383	0.671	127.780	141.360	190.560	80.670	2.356	0.642	122.070	145.670	190.050
8	90.290	2.724	0.690	169.670	178.090	245.970	91.610	2.707	0.660	163.680	186.300	247.990
9	101.640	3.093	0.708	222.740	221.900	314.400	102.270	3.055	0.676	211.270	230.110	312.390

URMS,3	IRMS,3	LAMBDA,3	P,3	Q,3	S,3	P,SIGMA	Q,SIGMA	S,SIGMA
19.937	0.450	0.518	4.646	7.667	8.965	13.867	23.716	27.482
29.673	0.737	0.568	12.428	17.989	21.865	38.473	57.020	68.803
40.774	1.064	0.597	25.911	34.789	43.378	78.500	107.400	133.050
51.781	1.404	0.619	45.010	57.100	72.710	137.720	177.830	224.970
61.657	1.708	0.633	66.720	81.510	105.340	203.400	251.980	323.880
70.740	1.997	0.648	91.550	107.570	141.260	280.780	334.490	436.790
80.680	2.296	0.664	123.050	138.510	185.280	372.900	425.550	565.890
91.020	2.626	0.681	162.700	175.050	238.980	496.050	539.440	732.950
101.660	2.965	0.699	210.840	215.450	301.450	644.850	667.460	928.250

4 CONCLUSION:

Losses in induction machines occur in windings, magnetic cores, besides mechanical friction and wind age losses. They determine the efficiency of energy conversion in the machine and the cooling system that is required to keep the temperatures under control.

In the design stages, it is natural to try to calculate the various types of losses as precisely as possible. After the machine is manufactured, the losses have to be determined by tests. Loss segregation has become a standard method to determine the various components of losses, because such an approach does not require shaft-loading the machine. Consequently, the labor and energy costs for tastings are low.

On the other hand, when prototyping or for more demanding applications, it is required to validate the design calculations and the loss segregation method.

The input-output method has become standard for the scope. It is argued that, for high efficiency machines, measuring of the input and output Pin, Pout to determine losses Σp on load.

Copper is a good material for induction motor rotors, reducing size and weight. Higher conductivity = higher efficiency, now that rotor manufacturing issues have been solved. Induction motors are a good solution for traction applications, with high efficiency and no serious issues with faults.
According to our measurement of three-phase motor, arrived at the conclusion that in order to improve the performance of motor referring them, it would be necessary, application of new plates in the engine, apply better best material in that. In case of engine size would require subsided its weight and its own structure, this contest would be more costs to the manufacturer in redesigning a new structure.

5 .BIBLIOGRAPHY

[1] Becker, K. M. and Kaye, J. (1962): Measurements of adiabatic flow in an annulus with an inner rotating cylinder. *Journal of Heat Transfer*, **84**, 97–105.

[2] Flik, M.I., Choi, B.-I. and Goodson, K.E. (1992): Heat transfer regimes in microstructures. *Journal of Heat Transfer*, **114**, 666–74.

[3] Gardiner, S. and Sabersky, R. (1978): Heat transfer in an annular gap. *International Journal of Heat and Mass Transfer*, **21** (12), 1459–66.

[4] Gieras, F. and Wing, M. (1997): *Permanent Magnet Motor Technology – Design and Applications*, Marcel Dekker, New York.

[5] Hendershot, J. R. Jr. and Miller, T. J. E. (1994): *Design of Brushless Permanent-Magnet Motors*, Magna Physics Publishing and Clarendon Press, Hillsboro, OH and Oxford.

[6] Incropera, F. P., Dewitt, D. P., Bergman, T. L. and Lavine, A. S. (2007): *Fundamentals of Heat and Mass Transfer*, 6th edn, John Wiley & Sons, Inc., Hoboken, NJ.

[7] Jokinen, T. and Saari, J. (1997): Modelling of the coolant flow with heat flow controlled temperature sources in thermalnetworks. *IEE Proceedings*, **144** (5), 338–42.

[8] Klemens, P. G. (1969): Theory of the thermal conductivity of solids, in *Thermal Conductivity*, Vol. **1,** (ed. R.P. Tye), Academic Press, London.

[9] Lawrenson, P. J. (1992): A brief status review of switched reluctance drives. *EPE Journal*, **2** (3), 133-44.

[10] Lipo, T. A. (2007): *Introduction to AC Machine Design*, 3rd edn, Wisconsin Power Electronics Research Center, University of Wisconsin.

[11] Matsch, L. D. and Morgan J. D. (1987): *Electromagnetic and Electromechanical Machines*, 3rd edn, John Wiley & Sons, Inc., New York.

[12] Miller, T. J. E. (1993): *Switched Reluctance Motors and Their Controls*, Magna Physics Publishing and Clarendon Press, Hillsboro, OH and Oxford.

[13] Moody, L.F. (1944): Friction factors for pipe flow. *ASME Transactions*, **66**, 671–84.

[14] Rao, K. and Sastri, V. (1984): Experimental studies on adiabatic flow in an annulus with rough rotating inner cylinder, in *Heat and Mass Transfer in Rotating Machinery* (eds D. Metzger and N. Afgan), Hemisphere, New York, pp. 166–78.

[15] Saari, J. (1995): *Thermal Modelling of High-Speed Induction Machines*, Electrical Engineering Series No. 82. , Acta Polytechnica Scandinavica, Helsinki University of Technology.

[16] Saari, J. (1998): *Thermal Analysis of High-Speed Induction Machines*, Electrical Engineering Series No. 90. , Acta Polytechnica Scandinavica, Helsinki University of Technology.

[17] Schuisky, W. (1960) *Design of Electrical Machines (Berechnung elektrischer Maschinen)*, Springer Verlag, Vienna. SKF (1994) General catalogue from SKF. *Catalogue 4000/IV E*.

[18] Boldea, N. and Ion, S. (2002): *The Induction Machine, Handbook*. U.S.A : Library of Congress , 1016 s. Dostupné z : <www.crcpress.com>. ISBN 0-8493-0004-5.