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Double-voltage double-speed induction motor

***Abstract**. The paper deals with double-voltage double-speed induction motor. The motor is used in Polish copper mine where low voltage supply is being modernized – the voltage is being increased from 500 V up to 1 000 V. Double-speed induction motors are widely used in mines to drive fans. This solution is much cheaper and more reliable in comparison with induction motor supplied by frequency inverter. Possibility of electric motor speed decrease by 50% is often sufficient. In case of fan drive decrease of the motor speed two times the motor input power decreases then about eight times so this is extremely financially rewarding [2, 3, 4] Double-voltage double-speed induction motors are offered on the market but they consist of two different magnetic cores and windings. The motor presented in the article has only one magnetic core. The motor rotor has squirrel cage made of copper bars. The motor stator contains switchable winding which has 21 terminals which are connected to the 3 contactors. The supply of the presented motor is the same like in case of the standard Dahlander pole changing single-voltage double-speed motor supply.*

***Streszczenie.** Artykuł dotyczy dwunapięciowego dwubiegowego silnika indukcyjnego. Silnik jest używany w polskiej kopalni miedzi, w której sieć zasilająca niskiego napięcia jest modernizowana – napięcie znamionowe sieci jest podnoszone z 500 V do 1 000 V. Silniki indukcyjne dwubiegowe są powszechnie używane w kopalniach do napędu wentylatorów. To rozwiązanie jest znacznie tańsze i pewniejsze w porównaniu do silników indukcyjnych zasilanych przez falownik. Możliwość obniżenia prędkości obrotowej silnika o 50% jest często wystarczająca. W przypadku napędu wentylatorów dwukrotne obniżenie prędkości obrotowej silnika powoduje obniżenie wejściowej mocy silnika o około 8 razy, dlatego to rozwiązanie jest wyjątkowo ekonomiczne [2, 3, 4]. Dwunapięciowe dwubiegowe silniki indukcyjne są oferowane na rynku, ale składają się one z dwóch osobnych magnetowodów i uzwojeń. Silnik prezentowany w artykule posiada tylko jeden magnetowód. Wirnik silnika posiada zwartą klatką wykonaną z prętów miedzianych. Stojan silnika posiada uzwojenie przełączalne posiadające 21 zacisków, które są podłączone do 3 styczników. Zasilanie zaprezentowanego silnika jest identyczne jak zasilanie standardowego jednonapięciowego dwubiegowego silnika z uzwojeniem stojana w układzie Dahlandera. (**Dwunapięciowy dwubiegowy silnik indukcyjny**)*

Keywords: induction motor, double-voltage motor, double-speed motor
Słowa kluczowe: silnik indukcyjny, silnik dwunapięciowy, silnik dwubiegowy

Introduction

In Polish mines supply voltage is being increased. In case of low-voltage supply the voltage is being increased from 500 V up to 1 000 V. In case of medium voltage supply the voltage is being increased from 6 kV up to 10 kV. Due to that voltage drops and power losses (due to current flowing) are being decreased. Moreover, the maximum length of the supply lines is higher.

This process is long-lasting. During the process “old” (before increase) and “new” (after increase) voltages are simultaneously utilized. It needs from electric motors to be universal. In case of low voltage motors it means the motors should be adjusted both for 500 V supply or 1 000 V supply. The ratio of the voltage values k_U=2 so motor stator winding star-delta reconnection cannot be applied. It could be applied if the ratio would be $k_U=\sqrt{3}$. The ratio k_U=2 can be fulfilled by change of the motor stator winding parallel branches by 2. In case of double-voltage single-speed induction motors this solution is quite easy. What about double-voltage double-speed induction motors?

The authors of the article asked themselves whether production of double-voltage double-speed induction motor with voltage ratio k_U=2 and with one magnetic core is possible?

Motor project

The projected induction motor has to fulfilled some requirements:

— it is dedicated for fan drive,

— it is adjusted both for 500 V or 1 000 V three-phase 50 Hz voltage supply,

— the motor pole pairs must be switchable from $2p$=2 (n_s=3 000 rpm) to $2p$=4 (n_s=1 500 rpm),

— only 3 contactor can be utilized to change of the motor pole pairs, like in case of the standard Dahlander pole changing single-voltage double-speed motor supply,

— motor rated power for $2p$=2 should be equal to P_n=50 kW and for $2p$=4 should be equal to P_n=8 kW. The projected motor fulfilled all above requirements. Motor stator contains a little bit modified standard Dahlander pole changing single-voltage double-speed motor supply [2, 6].

After basic engineering calculations FEM motor model was built in Ansys Maxwell software. In the Figures 1–2 motor magnetic pole and current density for the number of the motor pole poles $2p$=2 and $2p$=4 are presented. The motor was loaded by its rated load: 50 kW for $2p$=2 and 8 kW for $2p$=4.

Special stator winding was applied. Four stator winding configurations are able to be utilized: for two rated synchronous speeds $n_{2p=2}$=3 000 rpm or $n_{2p=4}$=1 500 rpm and for two rated supply three-phase voltage U_{HV}=1 000 V or U_{LV}=500 V. The stator windings scheme is presented in Figure 3.

a)
b)

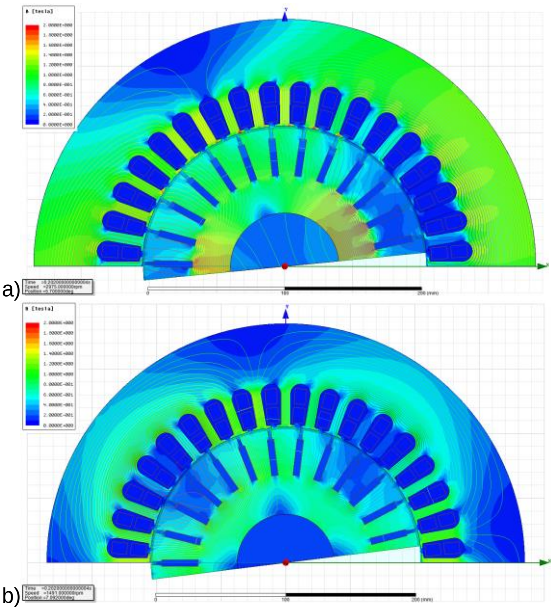

Fig.1. Motor magnetic pole for the number of the motor pole poles: a) $2p$=2 (P_{load}=50 kW) and b) $2p$=4 (P_{load}=8 kW)

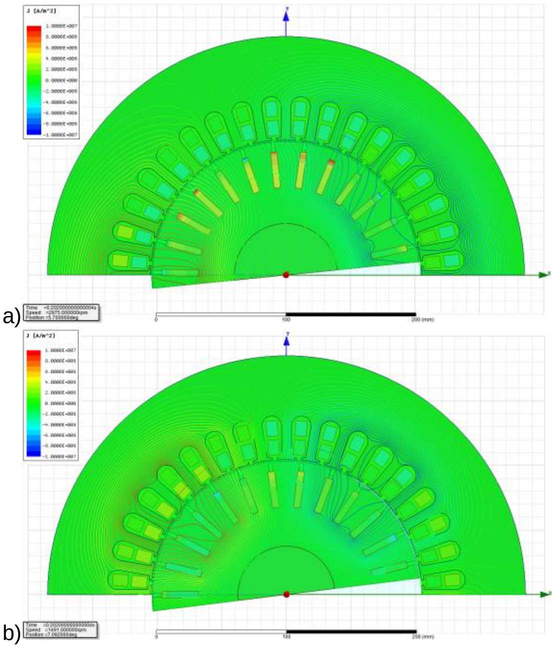

Fig.2. Motor current density for the number of the motor pole poles: a) $2p$=2 (P_{load}=50 kW) and b) $2p$=4 (P_{load}=8 kW)

The motor terminals are shown in the Figure 4. The motor has 21 terminals. By metal strips the motor can be reconnected to the one of the two rated motor voltage. By 3 contactors the motor stator winding can be reconnected to change of the motor pole pairs: $2p$=2 or $2p$=4, like in case of the standard Dahlander pole changing single-voltage double-speed motor supply.

During FEM motor model computations only half of the motor was utilized. To change of the motor pole pairs the phase supply 3-phase voltage sequence and FEM model boundaries (for $2p$=4 *slave*=*master* and for $2p$=2 *slave*= –*master*) must be changed. This solutions limits time of the computation about 50% and requires even number of the rotor slots.

After positive verification of the FEM double-voltage double- speed induction motor model running and starting properties of the motor model were investigated. Obtained results are shown in the Table 1. Motor performance, especially efficiency and power factor, is similar to the single-voltage double-speed induction motors performance which are offered on the market for example by ABB or Cantoni Group [7, 8]. Quite low value of the motor power factor for lower speed ($2p$=4) for rated load power P_{load}=8 kW is caused by the significantly unexploited magnetic core for this number of the motor pole pairs. Moreover, due to much lower value of the magnetic flux for $2p$=4 motor starting torque t_r=0,4 of the rated torque for rated power P_n=50 kW and rated speed synchronous n_s=3 000 rpm is low but enough in case of fan drive. This type of drive needs starting torque of the motor about t_r≈0,2–0,3 [1]

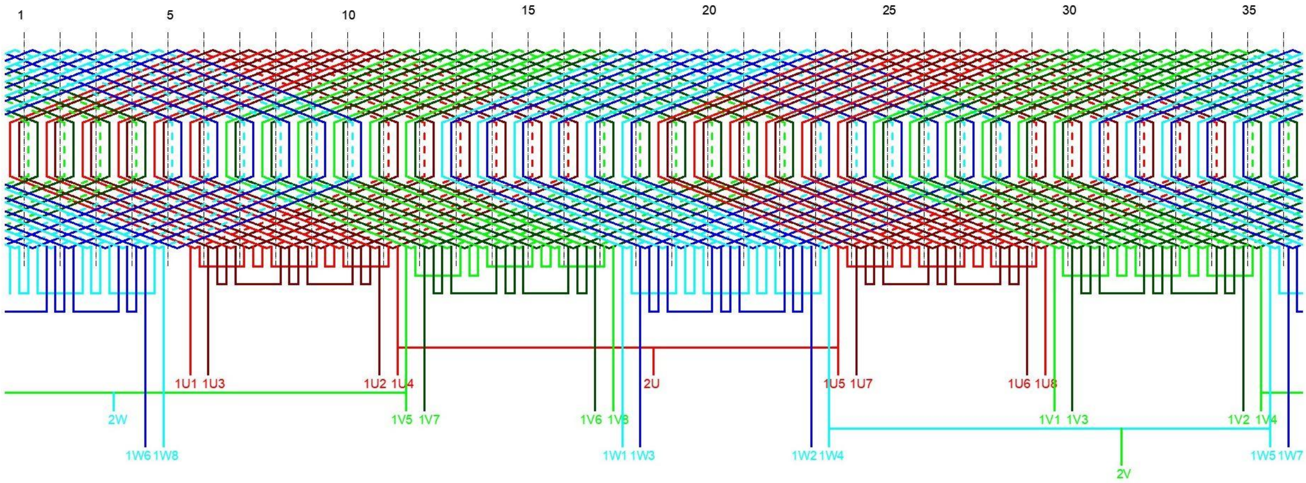

Fig.3. Double-voltage double-speed induction motor stator winding scheme

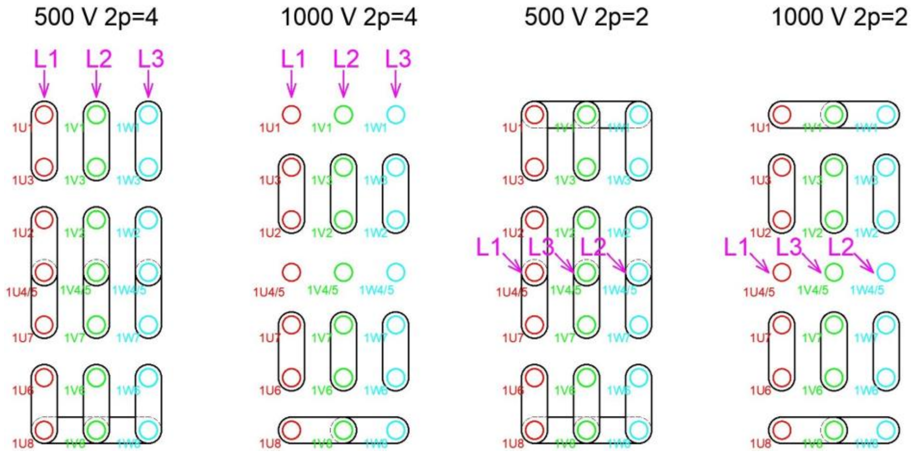

Fig.4. Double-voltage double-speed induction motor terminals

Table 1. Motor properties

$2p$	-	2	4
P_n	kW	50	8
U_n	V	1000/500	
n_n	rpm	2975	1491
η_n	%	93,5	88,8
$\cos\varphi_n$	-	0,90	0,60
$I_{n\_U=500V}$	A	69	17
$I_r/I_{n\_2p=2}$	-	8,1	1,6
$T_r/T_{n\_2p=2}$	-	1,0	0,4
T_{max}	Nm	530	211
connection	-	YY	Y

Motor project

After FEM motor model computations and obtained results investigation physical double-voltage double-speed motor model was manufactured by KISIELEWSKI. Manufacturing motor process is presented in the Figures 5–7.

Fig.5. Machining of the motor enclosure

Fig.6. Winding stator coils made by enamelled copper wires

Fig.7. Finished double-voltage double-speed induction motor P_n=50/8 kW, n_s=3 000 / 1 500 rpm to drive a fan

Summary

Double-voltage double-speed induction motor with one magnetic core and one switchable stator winding with rated voltage ratio k_u=2 is possible to manufacture. The motor terminal box has 21 terminals. The motor supply needs 3 contactors like in case of the standard Dahlander pole changing single-voltage double-speed motor supply. The cost of production of single magnetic core double-voltage double-speed induction motor is about 20% less in comparison with standard double magnetic core double-voltage double-speed induction motor.

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