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ONLINE MACHINE PARAMETER ESTIMATION FOR DIRECT TORQUE CONTROL

For DTC control monitoring the actual value of stator resistance is important. Based on previous investigations it is shown that the accuracy of online stator resistance monitoring of AC-machines fed by PWM inverters when using the superposition method suffers from dead time effects. A new and simple correction procedure is proposed to achieve high measurement accuracy without using temperature sensors. No additional hardware is required for this method. Experimental results are presented.

У режимі прямого управління моментомасинхронного двигуна пропонується моніторинг фактичного значення опору статора з використанням нових простих процедур, за рахунок чого досягається висока точність вимірювань без використання датчиків температури обмотки. Результати теоретичного аналізу співставлені з експериментом.

В режиме прямого управления моментом асинхронного двигателя предлагается мониторинг фактического значения сопротивления статора с использованием новых простых процедур, за счет чего достигается высокая точность измерений без использования датчиков температуры обмотки. Результаты теоретического анализа сопоставлены с экспериментом.

One of the main advantages of generic direct torque control (DTC) scheme compared to field oriented control is that only the stator parameters must be known for correct flux tracking [10]. Knowing the stator resistance could be also used for temperature monitoring purposes.

Temperature monitoring of electrical machines during operation is important for the prevention of overheating and lifetime reduction. According to Montsinger's rule an increase of the winding temperature by 10 K reduces the expected lifetime to roughly one half. In machines of large rating temperature sensors, usually PT100-sensors, are placed between the stator winding slot parts during production. However, such temperature sensors are usually not implemented in many medium and most low power machines, and retrofit would be difficult.

In the absence of temperature sensors the resistance method is preferred to determine winding temperatures [1]. Using the temperature coefficient $\alpha=\Delta R/R_{20}$ the winding resistance R_{ϑ} at temperature ϑ is given by the well-known linear relationship:

$$R_{\vartheta} = R_{20} \cdot \left[1 + \alpha \cdot \left(\vartheta - 20°C\right)\right], \qquad (1)$$

where α is the temperature coefficient of the conductor material.

For practical application it is however important to perform the measurement without interrupting the machine operation. This can be done using the injection of a dc current component superimposed to the ac winding current by means of an external dc voltage source as proposed in [2]. The resulting dc voltage drop is then measured by means of a filtering device. This method is not widely used in industry because of bulky equipment needed for its implementation.

Another way to obtain the actual value of the stator resistance is an adaptive estimation based upon machine models [3]. However, this estimation relies on other motor parameters which cannot be directly measured during operation. Hence the method suffers from significantly reduced reliability and accuracy of the estimation .

A method of stator resistance measurement for line-connected machines is described in [4]. By means of an external electronic device a controllable dc voltage offset is injected in one phase, leading to a dc current offset. Knowing the of dc voltage and dc current offset values,
the actual stator resistance value can easily be calculated. The dc offset is applied only for short time intervals, in order to reduce extra losses and to avoid undesired torque pulsations during operation. Using this method, a sufficient accuracy was reported.

The aim of this work is a stator resistance measurement method for inverter-fed induction machines, performing the measurement during machine operation without needing additional devices for dc voltage injection and for its measurement.

In the case of inverter-fed machines, there is no need for additional hardware, since a dc voltage offset can be easily generated by adjusting the inverter control [5, 6]. For the applied sine-triangle comparison method a dc voltage reference is simply added to the sinusoidal reference signal. The offset reference may also be implemented when other methods of PWM generation are used. Most inverters contain current sensors for phase currents, but the output voltage is rarely measured. Hence the aim is to develop a method which relies solely upon dc current offset measurement, without the need for dc voltage offset determination.

An output voltage measurement can be avoided by taking the cold state of the motor as reference, when the ambient temperature is known and the stator winding resistance can be measured by the conventional method at standstill (with external dc voltage source). Thereafter, the drive is started and a small dc offset command is superimposed to the inverter reference; the resulting dc offset current is then measured. When the dc offset voltage is considered independent of motor load, the product of dc current and stator resistance also remains constant. Taking 25° C, the temperature of the cold winding, as reference, the stator resistance at temperature ϑ can be calculated by the following expression:

$$R_{\vartheta} = R_{25}\frac{I_{dc25}}{I_{dc\vartheta}}, \qquad (2)$$

where R_{25} and I_{dc25} at 25°C are known from an initial test. An example result from a motor 2,2 kW using this method is shown in fig.1,a. The graph illustrates the "measured" winding resistance values from (2) versus temperatures measured by external resistance measuring devices, while the "theoretical" straight line reflects (1). The deviations increase with rising temperatures.

Dead-time effects in the inverter were identified as the main reason of the measurement errors when using (2) [7, 9]. Although the dead-time voltage amplitude is known, it takes an effort to consider it in calculations, since the number of switching actions must be counted online for each current polarity and the exact current zero crossing determination is a non-trivial task. Also the time difference between the current half-wave durations is difficult to account for.

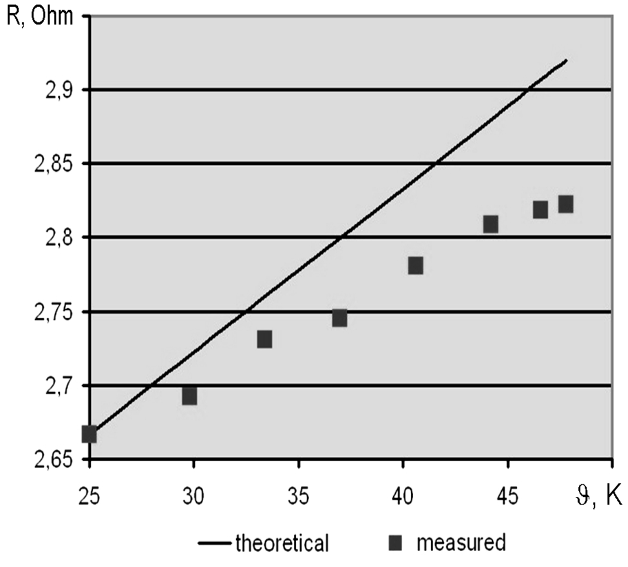


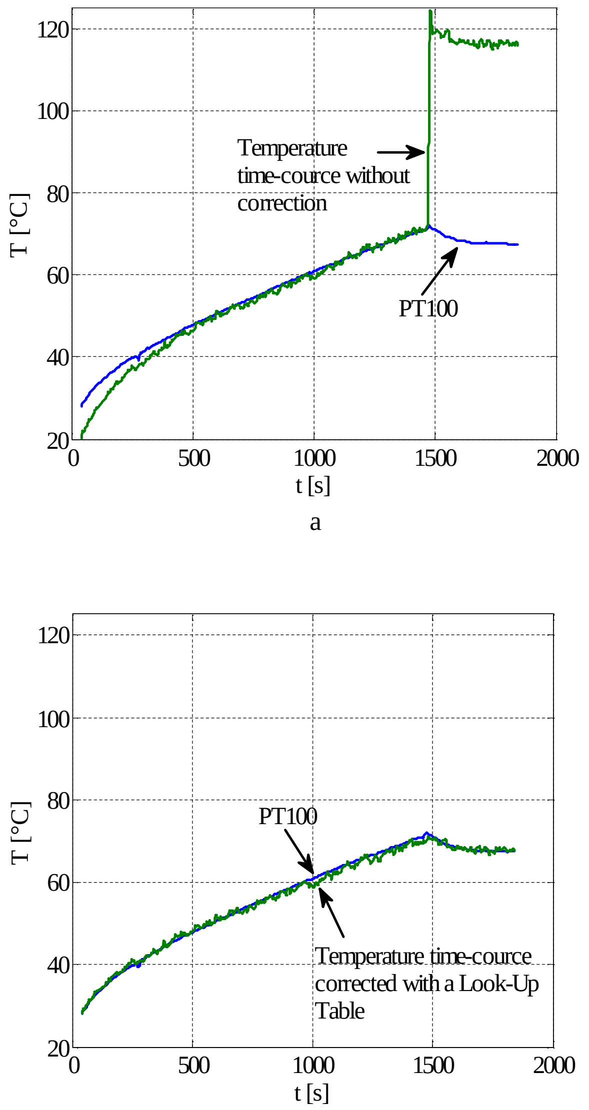
Fig.1. Resistance measurement on the PWM inverter fed motor

In order to improve the measurement accuracy of the method when using conventional PWM, the additional dc voltage component appearing at different operation conditions should be taken into account. This can be performed with sufficient accuracy by determining the dc current component as a function of ac current at constant dc voltage command. The measured dc current values are then multiplied with the stator winding resistance values at the time the measurement was performed. These values $U_{dc,cor}=f(I_{rms})$ are then stored in a look-up table. They form a calibration function from which corrected dc voltage values for a given dc voltage command are taken. The correct resistance value is then calculated as follows:

$$R_{\vartheta} = \frac{U_{dc,corr}}{I_{dc\vartheta}}. \qquad (3)$$

Using measured dc current component values to calculate temperatures without correction would lead to significant deviation from the actual temperature (fig.2,a). Applying corrected values from the look-up table, a highaccuracy is obtained (fig.2,b).

Large temperature errors occur after a step of the current amplitude by load variation, if no correction is applied; in the presented example it exceeds 50 K. Introduced correction allows to reach high degree of accuracy for the stator resistance and temperature estimation. This method operates with the conventional PWM and does not require additional hardware.



a

b

Fig.2. Temperature measurement with conventional PWM: without deviation compensation (a); with deviation compensation from the look-up table (b)

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