MEASUREMENT OF THE SWITCHING FORCE WITHOUT FORCE SENSOR

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Summary At the railways, some parts of a high speed corridor are being finished at present. In these corridors, trains can reach the speed of up to 160 km per hour. Consequently, the demand on switch point machine computer diagnostics has arisen. This paper presents the way how it is possible to realize this demand in a very cheap manner and only with a small intervention into the existing connection of the interlocking system.

1. INTRODUCTION

The switching force needed for switching of the switch point machine is a very important magnitude. Unfortunately, the measurement of the switching force requires a special force sensor and also a special sensitive measurement instruments. To equip every switch point of a high speed corridor with this equipment is very expensive.

This paper presents the idea of whether the current or power input of the asynchronous machine that powers a switch point machine, is equal to the switching force. Current transducers are very cheap and it is possible to equip every switch point machine with them. The utilization of voltage sensors is also possible.

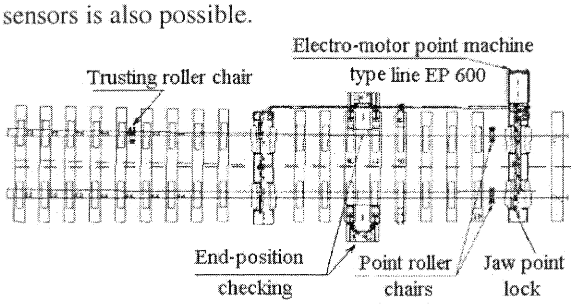

Fig. 1 The point type UIC 60 1:12-500.

2. PRESUMTIONS

In practice we can assume a balanced tree-phase supply network. Then we can use only one voltage transducer for the whole railway station. If we can assume also a balanced asynchronous machine of the switch point machine, we can measure only two phase currents. If the star point is not connected to the ground, the following equation is valid

$$I_U + I_V + I_W = 0 \qquad (1)$$

We can calculate the non-measured current from this equation.

The requirements placed on transducers are hereby minimized, and still it is possible to detect an unbalanced power network, a fall-out of one phase (when assuming asynchronous machine without any faults).

If we measure the voltage and current in each phase of asynchronous machine, we can calculate not only the real power input but we can also make the diagnostics the machine. As another advantage, we can determine turn short circuit of the winding, phase to ground short circuit etc.

3. POWER ANALYSIS SW

A general theory of how to determine the active and reactive power for three-phase systems is described e.g. in [1].

We can calculate the active, reactive and apparent power, power factor and other magnitudes with the help of the following relations. Root-mean-square value of voltage and current are given by relations (in general)

$$V_{RMS} = \sqrt{\left[\frac{1}{T}\int_0^T v^2(t)dt\right]}, \qquad (2)$$

where V is the voltage or current.

The instantaneous value of active power is derived from the instantaneous values of voltage and current

$$p(t) = u(t).i(t) \qquad (3)$$

Then we can calculate the average value of power in each phase, power factor of each phase and crest factor

$$P_{AVG} = \frac{1}{T}\int_0^T p(t)dt \qquad (4)$$

$$\lambda = \frac{P_{AVG}}{I_{RMS}.U_{RMS}} \qquad (5)$$

Thanks to these relations, we can evaluate power factor (Fig. 8).

The dominant component of the switching force is friction which depends on the friction coefficient, type of slide chairs, switch blades, ambient temperature, humidity, lubrication material etc.

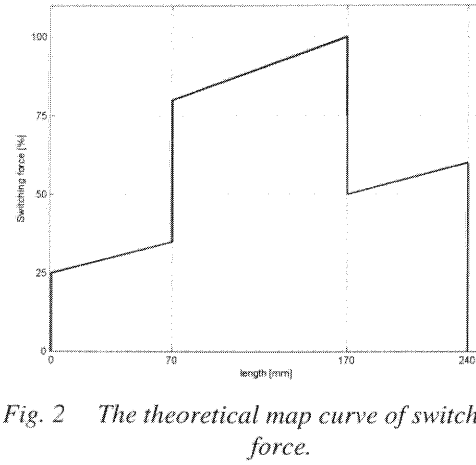

Fig. 2 The theoretical map curve of switching force.

4. MEASUREMENT ON SWITCH POINT MACHINE

The switch point machine has been tested separately, together with turnout and together on the brake. The results are shown in the following figures.

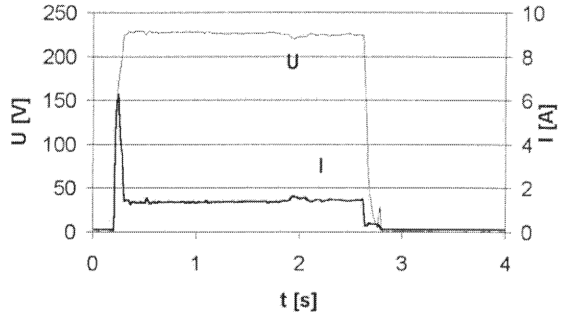

Fig. 3 Voltage and current as a function of time during throwing-over of the points

The first peak of current should be neglected. This is the starting current of the asynchronous machine. Thanks to the special clutch the asynchronous machine under the starting is without mechanical load. This peak of current is not significant for switching force, it could however be used for diagnostics of the asynchronous machine.

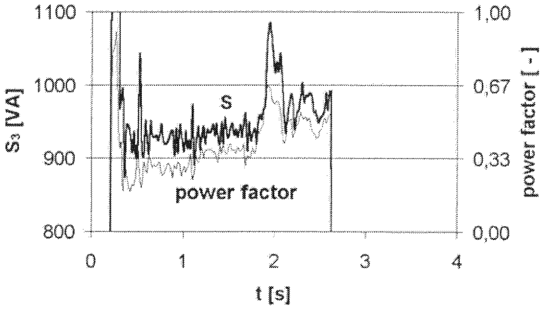

Fig. 4 Apparent power and power factor as a function of time during throwing-over of the points.

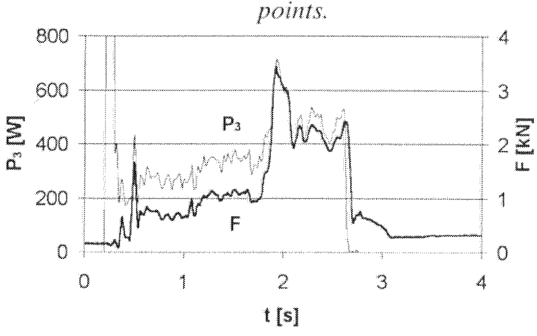

Fig. 5 Active power and switching force as a function of time during throwing-over of the points.

As follows from above presented figures, only the active power has a strong relevance with respect to the switching force. Measuring only the current is insufficient. We have to measure the voltage and current as well. From these magnitudes then we calculate active power. In order to confirm this consideration, the switch point machine was measured on a special mechanical break. The results are on the figures below.

5. MEASUREMENT ON SWITCH POINT MACHINE ON THE SPECIAL BREAK

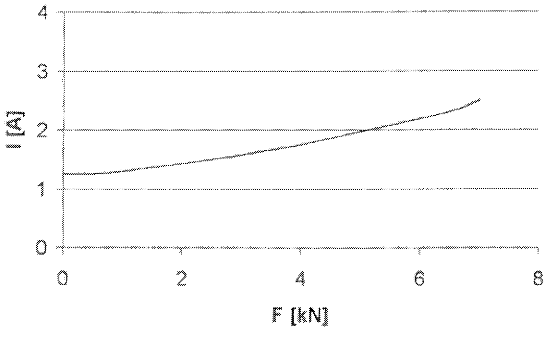

Fig. 6 Input current as a function of switching force of switch point machine.

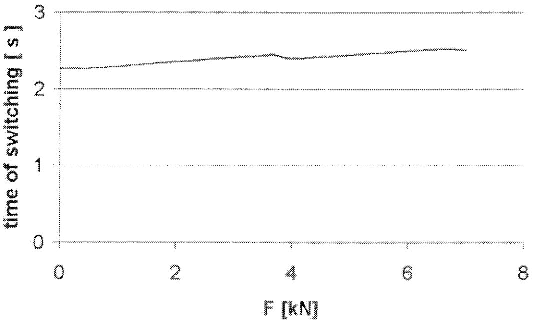

Fig. 7 Time of switching as a function of throwing-over force of point operating apparatus.

The slight fluctuation of the curve at 4 kN was caused by a change in the setting of the special clutch. This change consisted in increasing the maximum allowed switching force. Originally the maximum of switching force was set to 4 kN. During the measurement, as the force was increasing, the time of switching was increasing, too. This was caused by the ever rising clutch slip. When the value of 4 kN was reached, the switching did not succeed at all, the clutch was only slipping. However, as it was desirable to measure the characteristics for up to 7 kN at least, we had to set a higher allowed switching force.

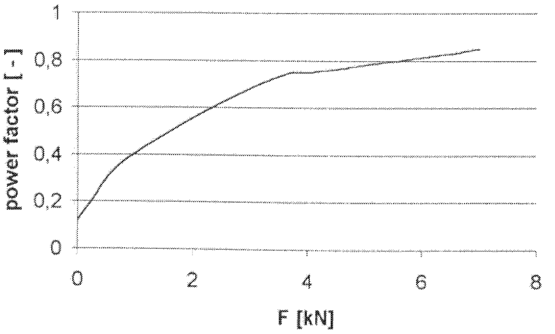

Fig. 8 Power factor as a function of throwing-over force of switch point machine.

Power factor, current, and apparent power are not linear dependencies on the switching force.

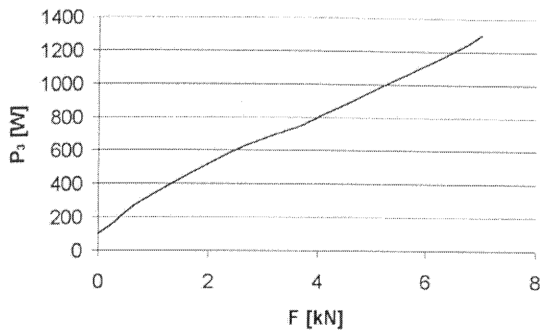

Fig. 9 Active power as a function of throwing-over force of switch point machine.

Only the active power displays linear dependencies. Nevertheless, the ratio of the active power and the switching force is not constant during throwing-over of the points.

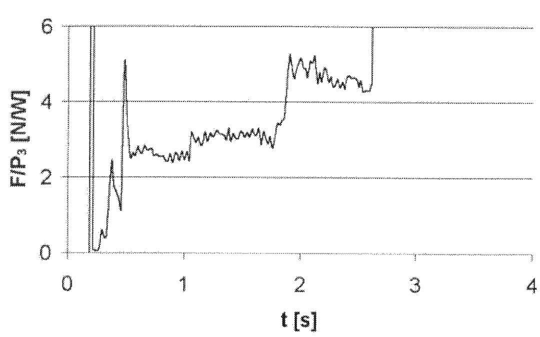

Fig. 10 Ratio of throwing-over force and power input of asynchronous machine as a function of time during throwing-over of the points.

The ratio of throwing-over force and power input of asynchronous machine is changing. With exception of the starting phase and elevating the first switch blade on the roller slide chair, we can see three almost constant levels. The first one is the motion of the first switch blade. The second one is the motion of both switch blades and the last one is locking of the first switch blade and throwing-over of the second switch blade.

6. DISSCUSSION, REMARKS

Map curve of switching from "+" position to "-" position could be completely different than reversing switching. On Figure 11 we can see the switching force corresponding to power input during the switching from "+" to "-".

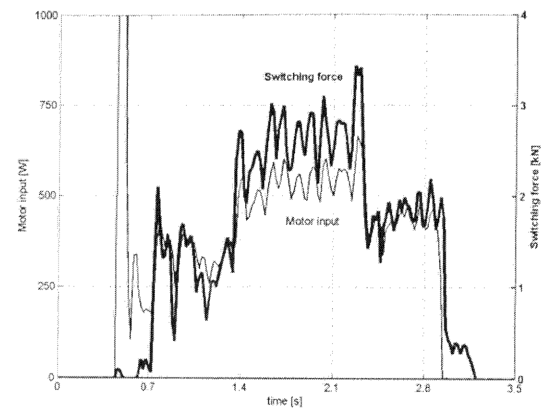

Fig. 11 The switching force corresponding to power input during the switching from "+" to "-".

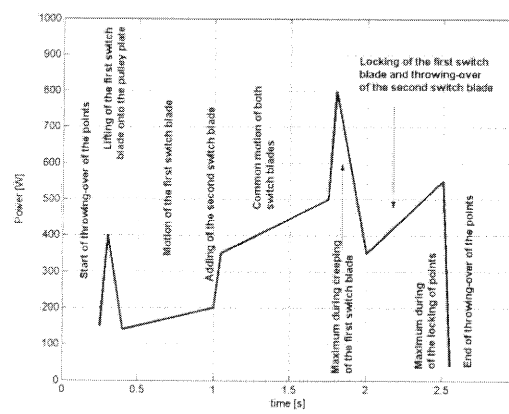

Fig. 12 The detailed description of the switching point movement activity.

As a contrast you can see on the two following figures the reversing switching, that is from position "-" to "+".

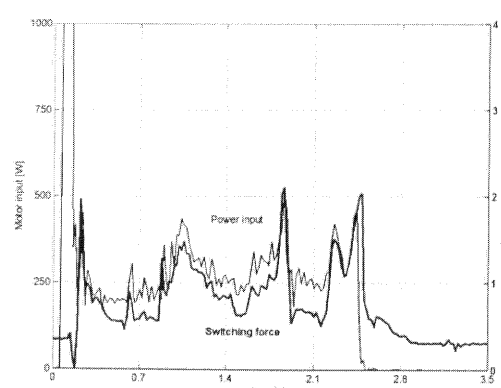

Fig. 13 The switching force corresponding to power input during the switching from "-" to "+".

The used method is very sensitive. For example. it is possible to detect internal mechanical problems of the switch point machine, which are impossible to detect by force sensor.

The force sensor was placed on the place of the pin, which mechanically connected the rod of the switch point machine with the rod of the switch.

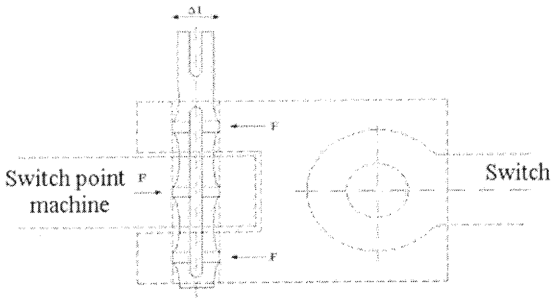

Fig. 14 Placing of force sensor

As a result of its location, the force sensor is only able to measure the outgoing force, not the inner force which is produced by the asynchronous machine.

We can see the non-constant power input, even when the mechanical break is completely disconnected from the switch point machine. This could be caused by the wrong tooth system of the switching rod, tooth system of clutch rim etc. After passing this hurdle, i.e. the wrong tooth, the power input is decreasing.

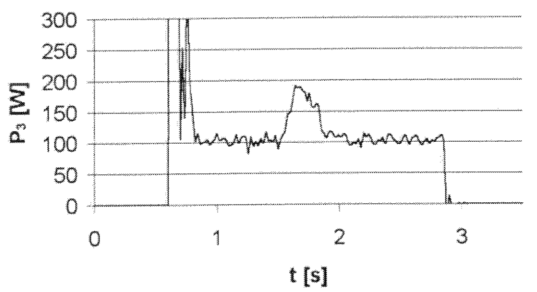

Fig. 15 Switch point machine under the no-load test.

7. CONCLUSION

It results from previously mentioned figures that only the power input of an asynchronous machine has a linear dependence on the switching force. The ratio between the switching force and the power input is a very good magnitude for replacing the switching force, which will not be measured in the final solution. This ratio depends on the type of the switch point, the type of switching blade, the ambient air temperature and humidity etc. Sometimes the opening tongue is relieved by the pulley which is placed on the slide chair. After having measured a few types of turnout, we determine the typical curves of power and switching force. Based on this database we can determine the switching force without a force sensor. The diagnostics of the switch will be produces automatically by the computer. From the curve of power input is possible to evaluate:

- Time of switching
- Tongue (switch blades) preload
- Peak of force during closing of a lock of the switch blades
- Stiff running of a switch blades
- Nonsymmetrical of current – prediction of error of an asynchronous machine

By this way is possible to predict an error of a switch point machine, improve the service and save lubrication material. The pollution of a natural environment will be also lower.

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9. NOMENCLATURE

U_{RMS}, I_{RMS}, V_{RMS} ...voltage, current, general magnitude (root mean square value)

u, i, p,v	... instantaneous value of voltage, current, active power, general magnitude
t	... time
T	... period
P_{AVG}	... average value of active power
λ	... power factor
k_v, CF	... crest factor
U,V,W	... phase index
F	... switching force
S_3	... apparent 3-ph power input
P_3	... active 3-ph power input

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