RELAXING OSCILLATION OF THE MACHINE-UNIT

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Summary To understand the behavior of the Earth´s geomagnetic field, many theories have been created. One of the possible approaches is the Rikitake dynamo and chaotic theory. This paper describes the first step, i.e. how to verify the chaotic theory simulated result by a practical test. This first step is the oscillating machine unit. The asynchronous motor working point is moving from the stable part of its torque characteristic to the labile part due to the enormous loading. In the labile part the speed slows down and loading has to be decreased. Then the motor moves back to the stable part of characteristic.

1. INTRODUCTION

The chaos theory is relatively new – just 3 decades. At present this theory is used for various purposes. Even last year somebody started thinking about the theory that the serious problems of a Europe transmission HV line in the network were caused by the chaos, not by violation of a "n-1 condition". The chaos simulation is no serious problem. However the difficulties start when we need the experimental verification, especially in electric machines. No engineer likes any instable system, usually it is dangerous or useless and everybody does his or her best to stabilize it.

Now we have the opposite problem – to design the unstable system. This is the first step on the way to the practical verification of chaos. The result will be useful for example for Rikitake dynamo which is used for description of a geomagnetism of a Earth.

To obtain the chaos, the following conditions have to be fulfilled.

- In the case of zero-input continuous-time causal systems, the existence of chaos is impossible if the order n of that system is lower than 3. It means that number of any energy accumulators have to be minimum 3.
- Further necessary condition for creation of the chaotic behavior is the existence of at least one "strong" non-linearity.
- Last condition is the possibility of unstable behavior. The unstable behavior does not have to be to infinity, i.e. the conditional instability is sufficient.

Please note that a chaotic system is not equal to a stochastic system.

In the branch of electrical machines we have few possibilities of how to obtain the oscillation. One possibility is to use the motor and dynamo with serial excitation, which are connected to a Ward-Leonard unit. This group of machines is not commonly used, the detailed description is in [1].

The second possibility is described in this paper.

2. THE DESCRIPTION OF THE EXPERIMENT

For the experiment the machine-unit consist of two asynchronous machines was used. Both machines are 4-pole machine. The smaller asynchronous machine of a power 11 kW is supplied by the regulated soft voltage source and works as a motor. The second one has a power of 12 kW and works as asynchronous self-excited generator.

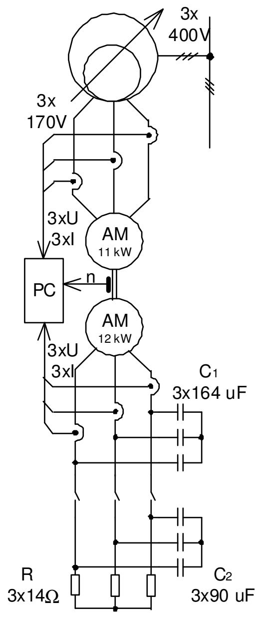

Fig. 1. The supply source of a motor, the asynchronous generator and measurement system.

The generated power is changed to heat in loading resistors. The power input of a motor and power output of a generator are measured. The speed of the machine unit is measured as well.

However the torque is not measured. It is calculated based on the speed and power input of the machine 11 kW.

$$M(t) = \frac{P(t)}{\omega(t)} . \tag{1}$$

The real efficiency of the motor is varying for various loading, however this variation is neglected in the first step.

3. THE SUPPLY SOURCE

For the above mentioned purposes the booster was used. This type of source is a relatively soft voltage source. This effect supports the oscillations. When we used another power supply source, the period of oscillation changed.

The principle of booster operation is based on the wound rotor asynchronous machine. The regulation is performed by the rotor displacement with respect of the stator. Due to the air gap and leakage reactance, the outgoing regulated voltage is very soft.

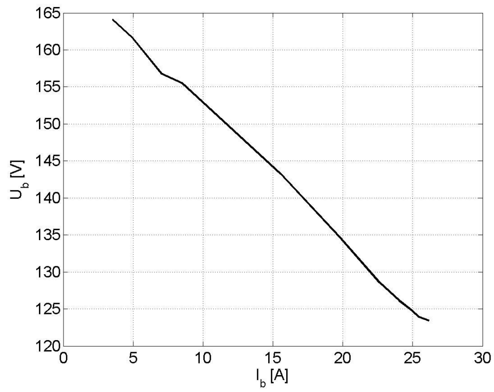

Fig. 2. The loading characteristic of a regulated power supply source.

4. ASYNCHRONOUS MOTOR 11 KW

The booster supplied the 4-poles asynchronous machine of a nominal power 11 kW. This machine works as a motor exclusively. Due to the lower voltage, the torque characteristic is not nominal. The torque depends on the voltage via general valid relation

$$T = \left(\frac{U}{U_n} \right)^2 . \qquad (2)$$

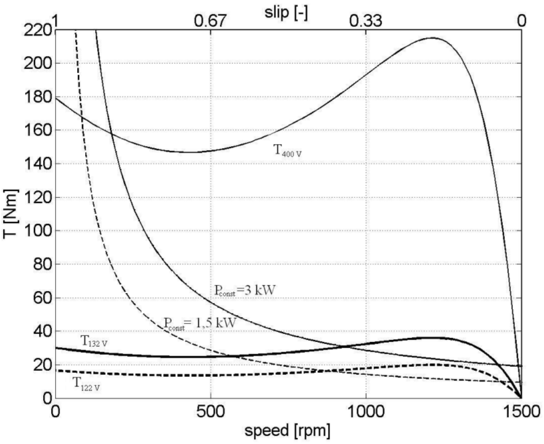

Fig. 3. The torque characteristic of a asynchronous machine 11 kW.

However, the voltage is not stable, it changes during one period of oscillation thanks to the varying of the load of the booster (see Fig. 5). Due to this fact the torque characteristic is varying in limits, determined by the appropriate voltage.

In Fig. 3 there are torque characteristics for the nominal voltage and for two lower line-to-line values (132 V and 122V). Between these values the voltage is varying.

The energy coming to the loading resistors is flowing not only from the mechanical power input of a generator, but also from the energy which is accumulated in the rotary mass of the machine unit.

The booster is able to recuperate the energy back to the network. However, in this case, this mode of operation failed.

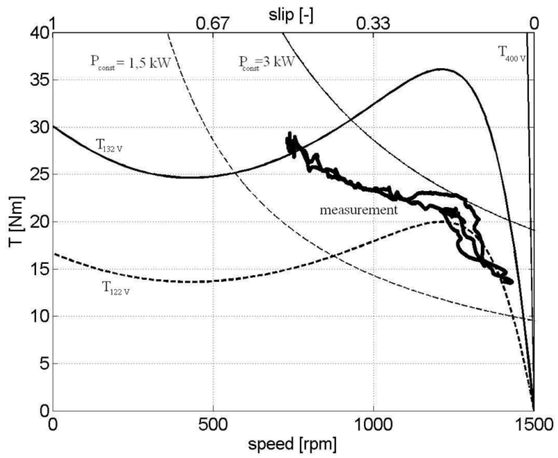

Fig. 4. The detail of the torque characteristic and the comparation with the measurement.

Consequently, the power input, power factor, speed and current of the machine 11 kW is varying in time.

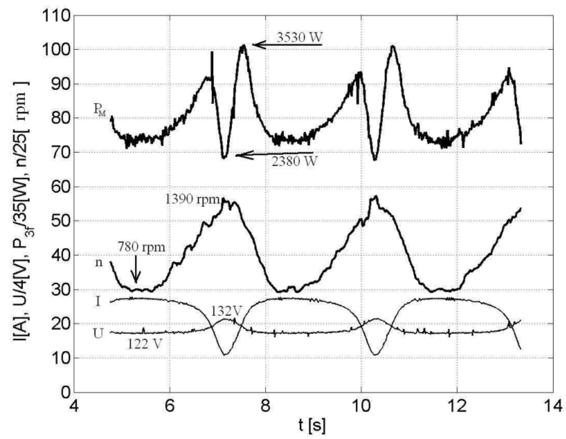

Fig. 5. The varying voltage, current, power input and the speed of the motor 11 kW vs time.

The speed of asynchronous machine is varying very strongly. The motor even exceeds the maximum torque point and starts to operate in the labile mode – labile part of the torque characteristic. Due to this fact the speed goes down, almost to one half of the nominal speed.

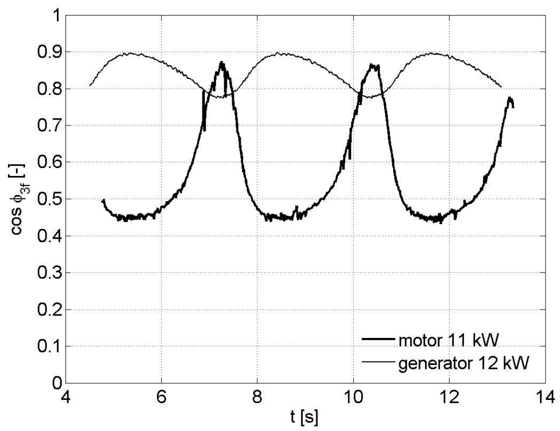

Fig. 6. The varying power factor of the motor 11 kW and generator 12 kW vs time.

5. SELF EXCITED ASYNCHRONOUS GENERATOR 12 KW

The general function of the self excited asynchronous generator is described in [3]. The capacity C_1 is carefully set to the value which reliably excites the generator to the nominal voltage under no-load mode of operation.
The second part of capacity is connected directly to the loading resistors. This capacity increases the magnetizing current when the generator is loaded.

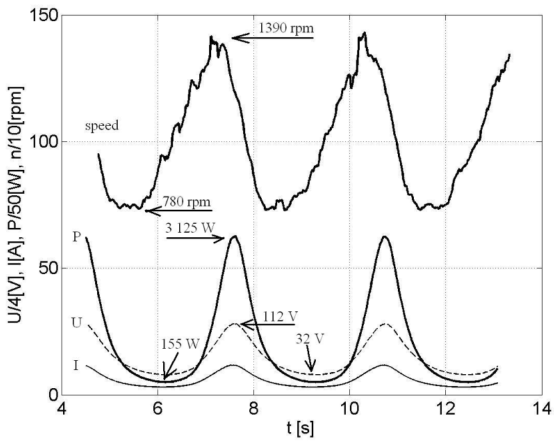

Fig. 7. The varying voltage, current, power output and speed of the generator 12 kW vs time.

The frequency of the generator 12 kW depends on the speed and on the electrical load. Under the nominal and no load condition the slip of the machine is almost zero. The small slip covers the losses in the stator winding only, which are caused by the magnetizing current. When the electrical load is increasing, the slip has to be negative (in the generator mode) and increasing as well, together with the torque of the motor. However, for this value of the torque, different synchronous speed is valid, because the asynchronous generator has to work with some slip when loaded. This rule holds for stable speed of the rotor. Nevertheless, in our case we have the speed varying simultaneously. The slip is varying up to almost 10% due to the lower supply voltage. Consequently, the torque is very low as was already shown above.

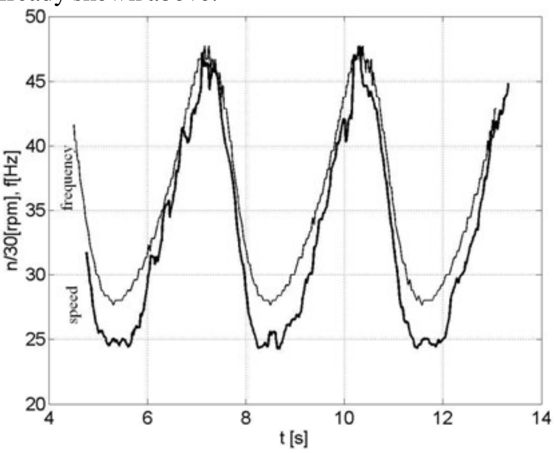

Fig. 8. The varying speed, frequency and slip of the generator 12 kW vs time

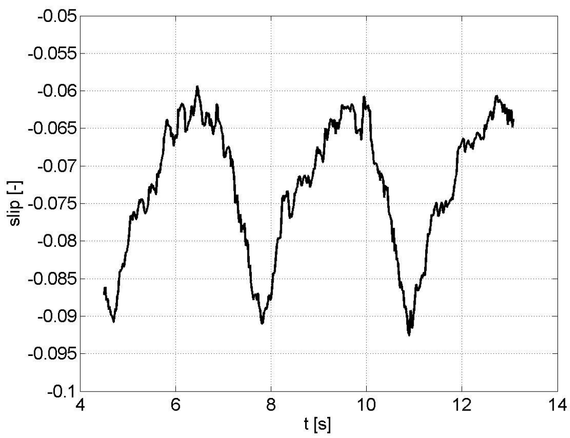

Fig. 9. The varying slip of the generator 12 kW vs time.

6. THE DESCRIPTION OF THE BEHAVIOUR

As was already mentioned above, the whole system has one main source of energy – an external power supply source.

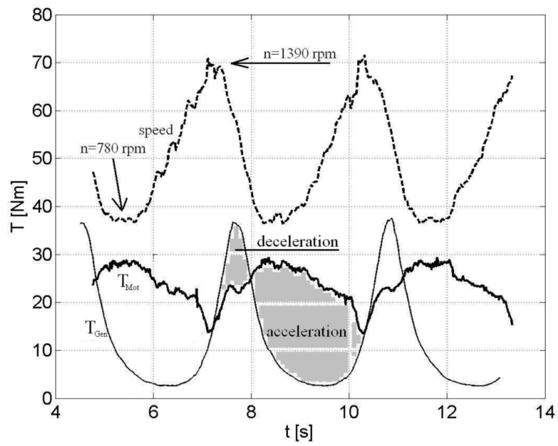

Fig. 10. The varying torque of the motor 11 kW and generator 12 kW, speed vs time.

Furthermore, there are additional 10 internal sources (6 inductances, 3 capacitors, 1 moment of inertia). The power input of the motor 11 kW is changing according to mechanical power. Part of this power input energy is accumulated in the rotating mass of the machine-unit. The rest of energy is as mechanical power input used by the generator.

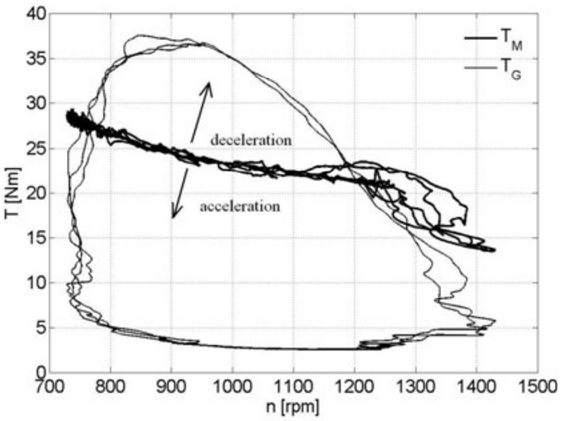

Fig. 11. The torque of the motor 11 kW and generator 12 kW.

This generator changes the mechanical energy to electrical energy and this energy is finally changed in the resistors to the heat. When the mechanical power input to the generator is not sufficient and the loading torque of the generator 12 kW is higher than mechanical torque of the motor 11 kW, the speed is decreasing.

The torque of motor 11kW and torque of generator 12 kW we can plot to the one system of coordinates.

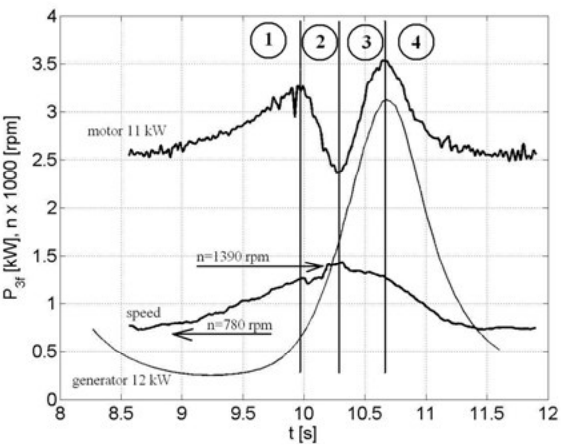

Fig. 12. The detail of the power of the motor 11 kW and generator 12 kW.

To describe the curve of an active power input of a motor 11 kW, we can divide one period of oscillation into 4 zones (see fig.11).

Zone No. 1. The power of the generator 12kW is very low and asynchronous motor 11 kW runs up. The speed is increasing, as well as its power input, because the power factor is increasing, as the speed of the motor is increasing. The end of this zone is in the point when the motor has maximum power input. The electric power is changing to mechanical power and speed is increasing, the energy is stored in the kinetic energy of the rotating mass – moment of inertia. The motor operates in the labile part of the torque characteristic.

Zone No. 2. The speed is approaching the synchronous speed, the power input and power factor of the motor is decreasing. The asynchronous generator starts to excite the capacitors and its power output is increasing, however the mechanical power output of the motor is sufficient to satisfy it. The motor operates in the stabile part of the torque characteristic.

Zone No.3. The power output of the generator is extremely increasing, consequently the motor increases its power input from the supply source up to the maximum. The generator has the maximum of its power output. The motor works at the maximum of the torque characteristic and further moves to its labile part. The speed is decreasing.

Zone No. 4. However, it is insufficient to satisfy the mechanical power input requirements of the generator. The supply voltage falls down, the motor power input falls down and speed is still decreasing. The generator decrease its power output and during this time the power is covered from the accumulated mechanical energy, i.e. from the kinetic energy. The motor operates in the labile part of the characteristic.

7. CONCLUSION

In this paper the oscillation of the machine-unit is described. At present the mathematical model being developed. The model will be used for the chaos theory. Also additional similar tests will be performed in the future. The various parameters will be changed and the result will serve for improving the mathematical model and putting more precision to it.

Notification

M, T	torque
U, I	voltage, current
P, S	active power, apparent power
f, cos φ	frequency, power factor
n, t	speed, time

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