16. Operation of the alternator in asynchronous operation

This operation is an emergency condition for most alternators due to a fault in the excitation circuit. Especially in the case of a partial fault, when the excitation circuit is closed, massive current surges are generated. Therefore, such an alternator condition is only permissible for a very short period of time. Possible causes of loss of excitation are:

- Short circuit of excitation winding directly or through an arrester
- Short circuit on the rectifier
- Disconnecting the excitation circuit

Short-term asynchronous operation can only be allowed with complete loss of excitation and under reduced active power load. This mode must be replaced by synchronous operation after a fault in the excitation system has been rectified or by deploying a backup excitation.

Once asynchronous operation occurs, the alternator tends to draw significant inductive reactive power (60 to 80% of S_N) from the grid to magnetize the circuit (similar to self-synchronization). This results in a voltage drop across the feeder busbars and self-consumption busbars. The reactive power deficit in the system is covered by the other alternators, but it is often necessary to shift the self-consumption to the standby supply.

Asynchronous operation occurs when the magnitude of the excitation current is so low that the braking synchronous torque is less than the turbine output and the alternator falls out of synchronism. As the alternator braking torque on the machine drops, the alternator will therefore begin to accelerate to supersynchronous speed. After balancing the resulting asynchronous torque and the reduced turbine torque, the resulting asynchronous torque has three components:

$$m_{AS} = \frac{u_S^{\,2}}{2}\left[\left(\frac{1}{x_d^{\,/}} - \frac{1}{x_d}\right)\frac{s\cdot T_d^{\,/}}{1+s^2 T_d^{\,/2}} + \left(\frac{1}{x_d^{\,//}} - \frac{1}{x_d^{\,/}}\right)\frac{s\cdot T_d^{\,//}}{1+s^2 T_d^{\,//2}} + \right.$$

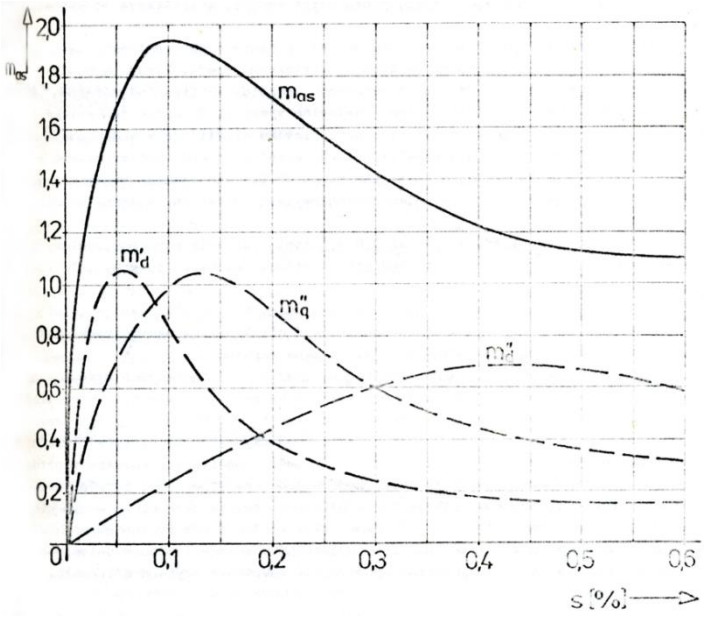
$$\left. \ldots + \left(\frac{1}{x_q^{\,//}} - \frac{1}{x_q}\right)\frac{s\cdot T_q^{\,//}}{1+s^2 T_q^{\,//2}}\right] = m_d^{\,/} + m_d^{\,//} + m_q^{\,//}$$

$m_d^{/}$ -component of the common flux of the excitation and damping windings in the longitudinal axis

$m_d^{//}$ -component of the variance flux change of the excitation and damping windings in the the longitudinal axis

$m_q^{//}$ -component of the damping winding flux in the transverse axis

The proportion of each component is:



For small slips the moment $m_d^{//}$ is negligible and the resulting moment is therefore evaluated only as:

$$m_{AS} = m_d^{/} + m_q^{//}$$

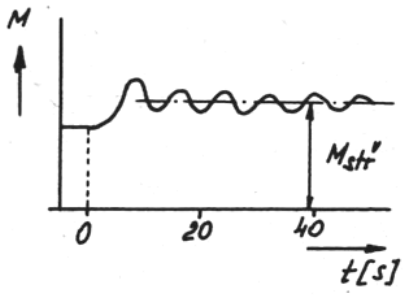
The conditions during asynchronous operation depend on the connection state of the excitation winding.

Excitation circuit disconnected

The rotor of an alternator can be considered as a cage of an asynchronous machine with variable active resistance (with less slip, currents enter more into the grooves and the resistance decreases) and negligibly variable inductance (magnetic asymmetry of the rotor). The rotor rotates at the speed $\omega_R = \omega_{synchr}(1+s)$, currents induced into the rotor create a field delayed compared to the rotor with angular velocity $\omega_r = -s \cdot \omega_{synchr}$. The field of rotor currents is drifted by the rotor with velocity ω_R, so that the rotor field does not move relative to the synchronous stator field $\omega_r + \omega_R = \omega_{synchr}$. Thus, a constant torque is generated and a constant active power is supplied to the grid, the pulsations of which are due only to the magnetic asymmetry of the damper in the longitudinal and transverse axes.

Closed excitation circuit

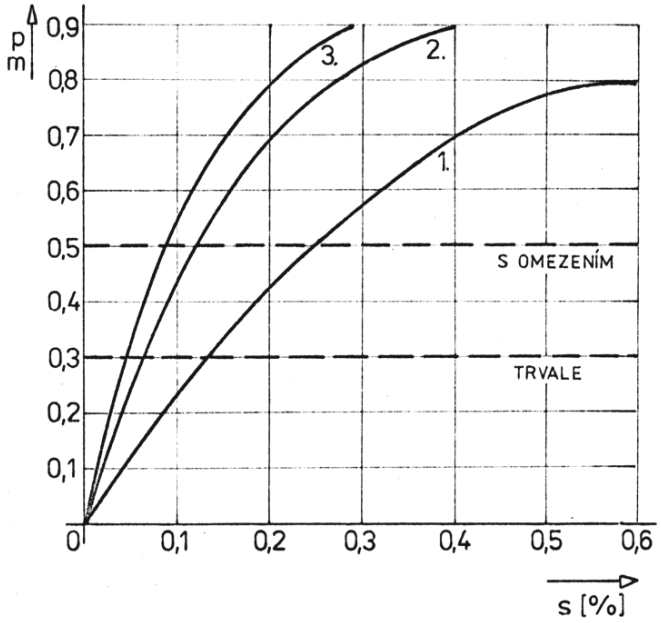
In this case, a current with a slip frequency is generated in the excitation winding. The resulting pulsating magnetic field is again carried by the rotor at a velocity of $\omega_R = \omega_{synchr}(1+s)$. We replace the pulsating field by two fields of half amplitude with mutual velocity $s \cdot \omega_{synchr}$. One component is at rest relative to the stator field, the other is rotating at speed $\omega_{synchr}(1+2 \cdot s)$ and induces additional currents in the stator of the appropriate frequency, causing strong pulsations of the stator currents.



The resulting machine moment is given by the superposition of the constant moments arising from the interaction of the non-rotating fields and the variable moments of the fields with different rotation speeds. The amount of wobble can be reduced by including a resistor in the circuit but this will reduce the mean

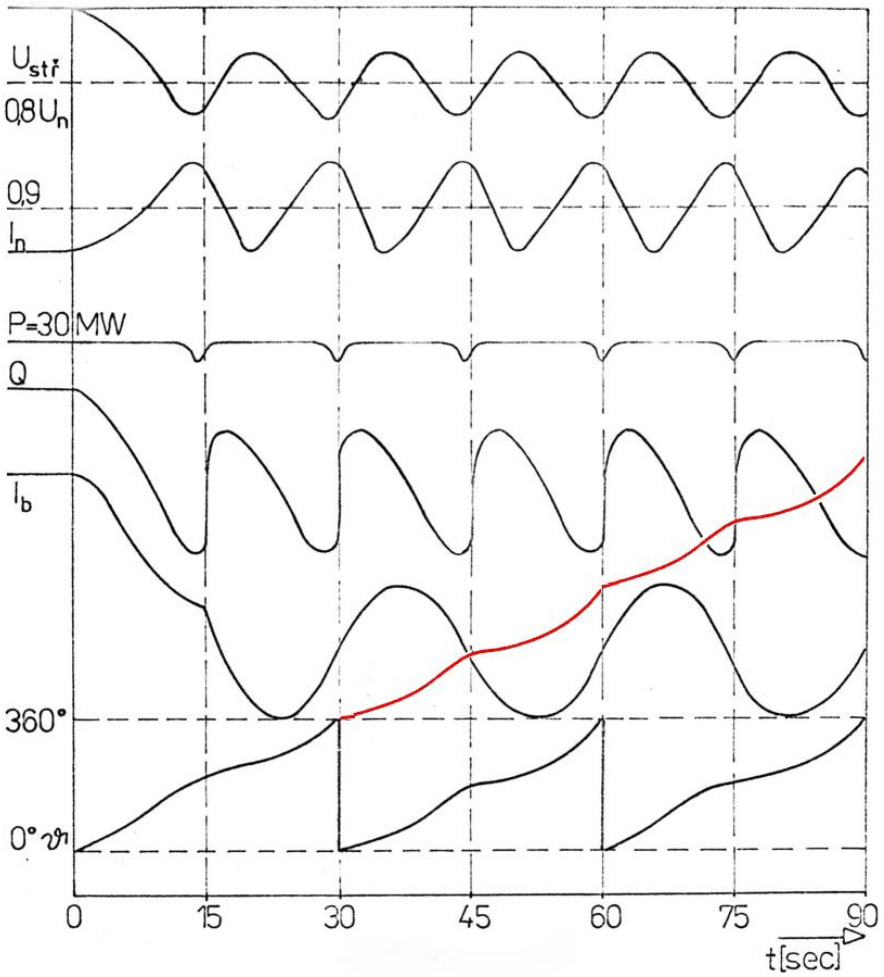
torque.

The magnitude of the mean (!) torque depends on the method of connection of the excitation winding:



1. The excitation winding is disconnected
2. The excitation winding is connected through a rectifier
3. The excitation winding is short-circuited

Flow of variables during asynchronous operation of the alternator:



Asynchronous operation is important to maintain the supply of active power to the system for major units. Dangers of asynchronous operation:

- The currents in the rotor and stator cause considerable heating
- A significant induced voltage is generated on the interrupted excitation winding
- Large inductive power draw and voltage reduction in self-consumption and the need to deploy a reservoir
- Large dissipative fluxes heat up the alternator faces (as in boosted synchronous operation)
- Fluctuation of power parameters

Currently, asynchronous operation is allowed due to good experience with large alternators where the resulting slip is small (0.3%) within these limits:

Power [MVA]	Within 10 minutes	Up to 30 minutes	Continuous running
62.5	0.6 P_N	0.5 P_N	0.4 P_N
125	0.5 P_N	0.4 P_N	0.3 P_N
235	0.5 P_N	0.4 P_N	0.3 P_N

The mean stator current must not exceed 1.05 I_N .
Asynchronous operation is not recommended for hydroalternators where there is less asynchronous torque (0.5 to 0.6 M_N), higher slip (3 to 5 %) and also greater rotor asymmetry (greater variation of quantities during asynchronous operation).

17. Operating modes of the alternator at extraordinary frequency and voltage values

Normal operation of the alternator is in the range of 49 to 50.5 Hz and 0.95 to 1.05 U_N . The percentage sum deviation of these quantities must not exceed 5%. Continuous operation of the alternator is capable of a range of 48.5 to 50.5 Hz and 0.8 to 1.05 U_N . Extraordinary operation is limited by time limits and rotor and stator current magnitudes of 1.05 ratings.