ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2006, Tome IV, Fascicole 1, (ISSN 1584 – 2665)
FACULTY OF ENGINEERING HUNEDOARA,
5, REVOLUTIEI, 331128, HUNEDOARA

STUDY OF PUMPS AND TURBINES TRANSITORY MODE DURING SWITCHING FROM STATIC FREQUENCY CONVERTER CONNECTION TO DIRECT CONNECTION TO THE MAIN SUPPLY

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Summary:
This works intends to clarify the current peaks which occur in the switching moment for a pump or turbine operating at rated speed, from static frequency converter connection to direct connection to the power supply. Furthermore, we are proposing a solution to prevent such over currents.

Keywords:
Over currents, pumps, turbines, static frequency converter, direct connection to the grid.

1. INTRODUCTION

Numerous applications are currently using the frequency static converters. For pumps or turbines, when the aim is a variable flow, a multiple units of equal power configuration can be used, of which one unit is supplied via static frequency converter.

When the unit supplied via the static frequency converter (CFS) reaches the rated speed, it is switched to direct connection to the power supply, while another unit is taken over by the CSF from zero speed.

Figure 1 presents a practical example: several pumps P_1, P_2, …, P_n are pumping the working fluid into a common piping system keeping a fixed discharge pressure, for all consumer's requirements. Each pump's motor can be supplied via CSF or directly from the power supply. The static frequency converter provides a flow fine-tuning by increasing pump's speed from zero speed to rated speed.

Legend:
CSF - static frequency converter
DMT - magneto-thermal switch
M_1, …, M_n - pumps' motors
P_1, …, P_n - pumps
K_{11}, K_{12}, …, K_{n1}, K_{n2} - contacts which enable switching the supply.

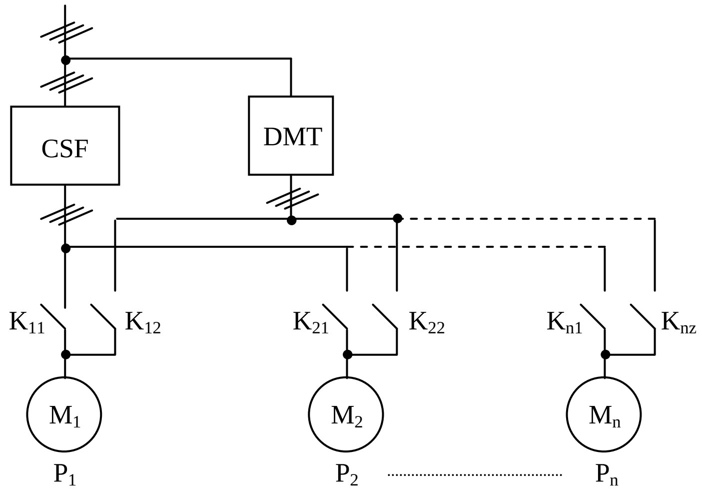

Figure 1. Example of pumps application

2. TRANSITORY MODE CALCULATIONS

Switching of pump's motor or turbine's generator from the connection via static frequency converter to direct connection to the grid could take in between 0.65 s and 0.75 s, depending on static frequency converter type.
The operational algorithm previous to switching is:

$$M - M_R = J_{ech} \cdot \frac{d\Omega}{dt} \tag{1}$$

$$M_R = M_{Ro} + M_{R_N} \cdot \left(\frac{\Omega}{\Omega_N}\right)^2 \tag{2}$$

where:

M	- pump motor electromagnetic torque
M_R	- pump or turbine load torque
M_{RN}	- load torque at rated speed
M_{Ro}	- load torque at idle run
J_{ech}	- system equivalent moment of inertia
Ω	- pump / turbine angular speed
Ω_N	- pump / turbine rated angular speed

After switching, the algorithm would be altered into the above specified equation:

$$0 - M_{R_0} - M_{R_N} \cdot \left(\frac{\Omega}{\Omega_N}\right) = J_{ech} \cdot \frac{d\Omega}{dt} \tag{3}$$

Solving the equation (3) leads to pump angular speed calculating in the moment of direct connection to the grid:

$$\Omega' = \frac{J_{ech} \cdot \Omega_N^2}{M_{R_N}} \cdot \frac{1}{\Delta t + \frac{J_{ech} \cdot \Omega_N}{M_{R_N}}} \tag{4}$$

where Δt stands for the duration of switching from supply via CSF to direct connection to the grid.

3. EXPERIMENTAL RESULTS

The measurements records and calculations were performed for a pumping system with the following rated technical data:

pump motor:
U_N = 380V a.c.
P_N = 110 kW
$\cos\varphi_N$ = 0.87
I_N = 206 A
Y stator connection
n_N = 980 rpm
η_N = 0.93
J_{ech} = 1 kgm^2

Frequency converter:
type ACS 800-02-0140-3
transitory time Δt = 0.7 s

From algorithm (4) it results:
Ω' = 12.4 rad/s, for Ω_N = 102.62 rad/s and Ω_1 = 104.72 rad/s

The rated slip

$$s_N = \frac{\Omega_1 - \Omega_N}{\Omega_1} = 0.02 \quad (5)$$

and the slip in the switching to direct supply connection moment is

$$s' = 0.8815 \quad (6)$$

The difference between relations (5) and (6) reveals the slip jump, which is actually a current jump.

$$\Delta s = s' - s_N = 0.8615 \quad (7)$$

The transitory conditions are severe, and the motor behavior is almost similar with the behavior during direct connection to the grid, when Δs = 1 – 0.02 = 0.98.

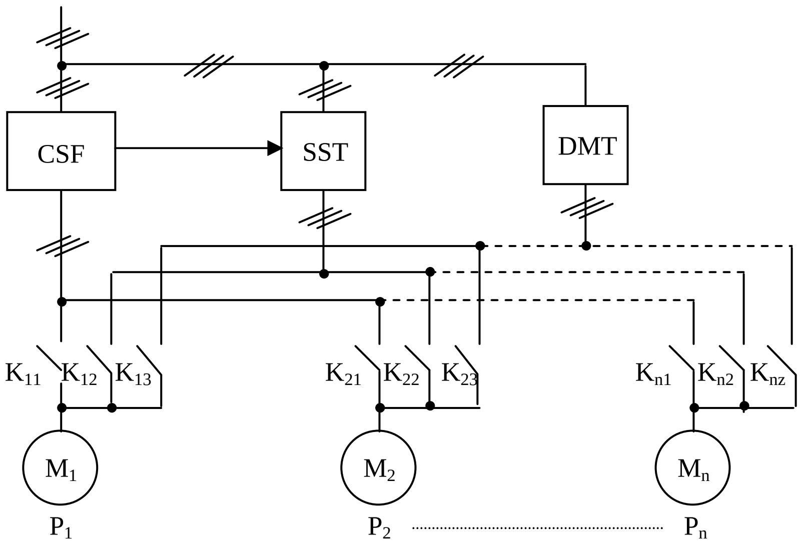

Figure 2. Configuration for over currents elimination

4. CONCLUSIONS

Based on experiments results, such switching procedure is not recommended for the circuits using static frequency converter.

Figure 2 below presents a proposal diagram that would eliminate the over currents problem.

When flow fine tuning is required, the CSF operates with a single pump. When flow increasing is required, the second pump P_2 is connected. Pump start-up is controlled by the soft starter SST; when pump reaches the rated speed, the motor is switched to direct connection to the supply using the DMT. Thus the transitory time is much shorter.

The other pumps start-up is handled in the same manner.

When a lower flow is required, the operating pumps are disconnected one by one. The flow jumps caused by pumps connection/disconnection are taken over by the pump supplied via CSF, which is decreasing or increasing its speed accordingly.

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