THE PERFORMANCE OPTIMISATION OF RESONANT ELECTROMAGNETIC VIBRATORY CONVEYORS USING CURRENT CONTROLLED TRANSISTOR POWER CONVERTERS

Abstract

The vibratory movements represent the most efficient way of granular and particulate materials conveying. Vibrations of tank, i.e. *"load-carrying element"* (LCE), in which the material is placed, induce the movement of material particles, so that they resemble a highly viscous liquid and the material becomes easier to transport. Different drive types can achieve mechanical vibrations of the conveying element. The very first drives were originally mechanical (pneumatics, hydraulics and inertial). Nowadays, most of the common drives are electrical. When a reciprocating motion has to be electrically produced, the use of a rotary electric motor with a suitable transmission is really a rather roundabout way of solving the problem. It is generally a better solution to look for an incremental-motion system with magnetic coupling, so-called *"electromagnetic vibratory actuator"* (EVA), which produces a direct "*to-and-from"* movement. Electromagnetic drives offer easy and simple control for the mass flow conveying materials. In comparison to all previously mentioned drives, these have a more simple construction and they are compact, robust and reliable in operation. Application of electromagnetic vibratory drives in combination with power converters provides flexibility during work. It is possible to provide operation of the vibratory conveyors in the region of the mechanical resonance. Resonance is highly efficient, because large output vibratory displacement is provided by small input power. Change of the mechanical resonant frequency, due to change of the conveying material mass, or even change of the spring stiffness, reduces efficiency of vibratory drive. An optimal and efficient operation requires tracking of resonant frequency.

The silicon-controlled rectifier (SCR) converters are used for the EVA standard power output stage. Their usage implies a phase angle control, which is very easy, but with many disadvantages. Varying firing angle provides the controlled *ac* or *dc* injection sinusoidal current in order to control mechanical oscillations amplitude, but not the tuning of their frequency, since conventional SCR controller operates at fixed frequency which is imposed by *ac* mains supply. These converters inject undesirable harmonics and *dc* current component into mains.

This dissertation presents a new and original approach relate to the performance optimisation and control of vibratory conveyors with electromagnetic drive. That approach is based on using switch mode transistor power converter as flexible link between vibratory conveying system and mains power. Offered solution exceeds the many disadvantages of SCR controlled drives. From electrical standpoint, the EVA is mostly inductive load by its nature, so that generating the sinusoidal or triangle half-wave current is reached by proposed transistor power converter with implemented current-mode control. It is consider and realized several ways of current control: tolerance band control (hysteresis control) and zero average current error control for generating sinusoidal half-wave current and programming current control (control of the peak current) for generating triangular half-wave current. It is concluded, that the LCE displacement has "smooth" sine characteristic, although the EVA current is pulsating. The current high-frequency ripple, due to the hysteresis control, does not effect to the LCE oscillation waveform. It is adopted programming current control with respect to the minimization switching losses, easy control and reliability of power converter, as the optimal solution.

The implemented transistor converter comprises two power converters. One is input *ac/dc* MOSFET converter with power factor correction, while the other one is *dc/dc* IGBT converter with pulsation output current, for driving EVA. Input converter is in fact a controllable transistor rectifier with two "*boost"* stages and inductance on the *ac* side. Output converter is realized with asymmetric half-bridge converter and it consists of two IGBT, on one bridge diagonal and two freewheeling diodes, on the other, opposite diagonal. Drive circuit is a high voltage and high-speed, with independent referenced output channels (high and low side). Floating channel is designed for "*bootstrap"* operation,

high voltage fully operational, tolerant of negative transient voltage and *"dV/dt"* immune. The reference value EVA current is determinate by two reference inputs: one for amplitude and duration and other for frequency. Both of these signals are controlled by the microcontroller, which is based on PC104 module. The actual EVA current is measured by the *Hall-effect*, compensated current sensor with galvanic isolation.

Only then, operation for vibratory conveying system does not depend on mains frequency. The compensation of load mass change is achieved by tuning the frequency, amplitude and duration of EVA coil current, i.e. frequency and pulse intensity of the excitation force, to be applied on the LCE. From the moment of load mass changing, it is necessary to locate the new resonant frequency upon which the oscillation amplitude of the LCE is being tuned. Consequently, frequency control provides operation of vibratory conveying drive in the region of the mechanical resonance, while amplitude control provides the keeping amplitude oscillation of the LCE. The LCE displacement is measured by non contact inductive sensor. In this way, the whole conveying system has a behavior of the controllable mechanical oscillator. Also complicated mechanical tuning is eliminated and electronics replace mechanical settings. The effectiveness proposed current controlled transistor power converter and performance optimization of electromagnetic vibratory conveying drive are verified by a simulation and experimental results. The simulation results are given in the program package PSPICE. Experimental results are recorded on the implemented transistor power converter and matched mechanical conveying system.