DIGITAL-TO-ANALOG BEAM ENERGY AND CURRENT STABILIZATION OF ELV ELECTRON ACCELERATORS

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Abstract

The methods of links between technology line and ELV accelerator control system are described. accelerator control system are described. The problems of the fast control of the beam current are revised. The method of improving the rising of beam current and stability of electron energy is shown.

INTRODUCTION

ELV industrial electron beam accelerator is effective instrument for radiation treatment applications. Especially frequently it is used in cable and heat shrink tube manufacturing. Accelerator is only a part of technology line. There are underbeam transportation line, take-up and pay-off systems, safety system etc… All of them are controlled by signals from ELV control system, which are generated on base of the values as electron energy and beam current. There are 2 well-known methods of controlling the transportation line. The first: there ELV is master, line is slave (see Fig. 1). What things are the most important for this method?

For accelerator:

- stable parameters (better stability – less inhomogeneity of absorbed dose);
- smooth beam operation (except dose inhomogeneity, fast beam current changes can break treated cable or tube).

For technology line:

- quick response for incoming parameters changes;

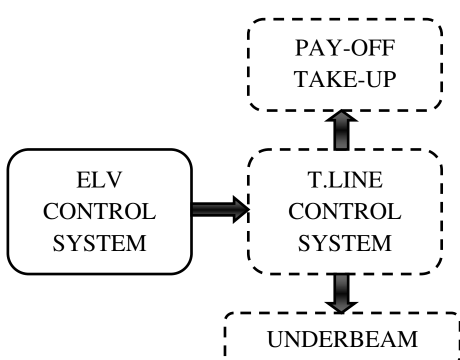

Figure 1: Accelerator is master.

Other method, where the accelerator is a slave, the technology line is a master, and accelerator parameters (beam current) follow production line velocity (see Fig. 2). Unlike the first method, here the most important things will be:

For accelerator:

- stable parameters (better stability – less inhomogeneity of absorbed dose);
- quick response for incoming parameters changes;

For technology line:

- smooth velocity;

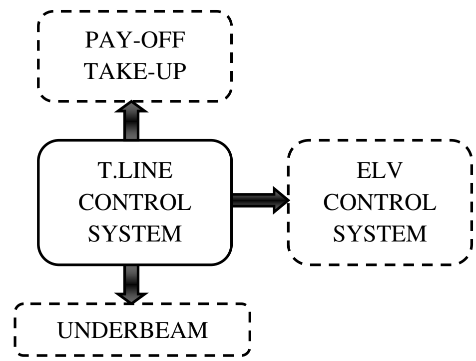

Figure 2: Technology line is master.

For second method the accelerator should provide enough performance and quick response.

New technologies of rubber component irradiation treatment are increasing the performance of technology lines, so they are using second method of links the accelerator to technology line. It led us to find possibility to increase the velocity of beam current control (speed of ascending/descending of beam current value).

STABILIZATION SYSTEMS

Systems of energy and current stabilization are based on analog PID-controllers. They provide good stability at sufficient speed-work. Energy stabilization system separated from current stabilization. It is enough fast (time constant is 0.5 sec) for 100 kW accelerator. Energy stabilizer output is directly connected to Pulse Width Modulator of power supply cabinet, and has feedback from energy sensor (it can be resistive divider or rotary voltmeter).

Current stabilizer is mix of analog PID and digital matrix. Current stabilizer is controlling heating of electron gun filament (heater of cathode), and has feedback from beam current sensor. Cathode heater has a big inertia, so time constant of analog PID should be about 3-5 sec. Low speed of PID is good for steady state, but seriously increases time of transient process. Digital matrix is software part of current stabilizer. Each matrix elements is delay, between present and next (or previous) moments of setting the beam current value to input of current stabilizer. Then during the beam ascend or

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descend, the matrix will set step by step all his elements to input of analog PID. This works well, while we operate with velocities about 0.5-1 mA per sec, but for fast beam ascending we should add in current stabilizer some module, which will have possibility influent (accelerate or decelerate) matrix.

Concerning energy stabilization: if the beam current is rising the accelerator energy is falling. It is due to the parameters of high voltage transformer and rectifiers. If energy decreases, energy stabilizer tends to return this to reference. So energy became stable. It was experimentally determined: more current speed caused more fall of energy (formula 1). Other words: the energy curve approximately follows to derivative of beam current (see Fig. 3 and 4).

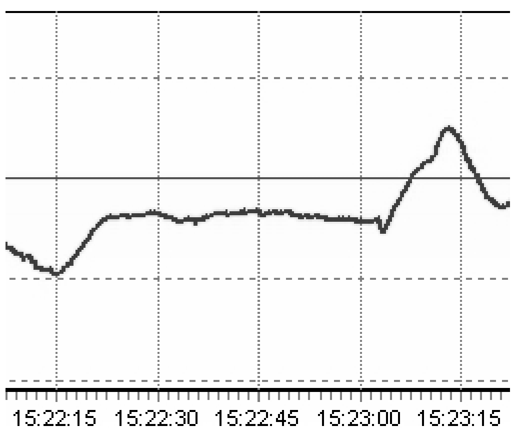

Figure 3: Accelerator energy curve.

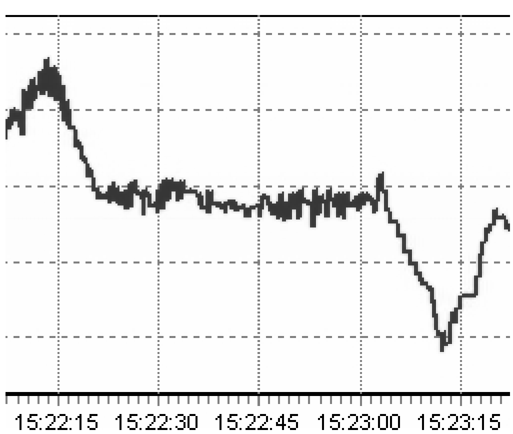

Figure 4: Current velocity curve.

UPGRADE

Finally, for accelerate beam current velocity we added three modules into accelerator software. First module is derivative calculator. Each 0.01 - 0.1 second this module calculate difference from previous and present beam current value. Output value is a beam current velocity, which is to be used in other two modules (see Fig. 5, new modules inside dotted line).

Second module is energy compensator. Using formula 1 and current velocity as an argument, module generates offset that will be mixed with energy DAC signal. . So the signal on input of energy stabilizer E will be in accordance with formula 1. This provides better stability of accelerator energy during beam current ascending or descending.

$$E = E_{ref} - V_{bc} * k \qquad (1)$$

Eref – reference energy;
Vbc – beam current velocity;
k – coefficient.

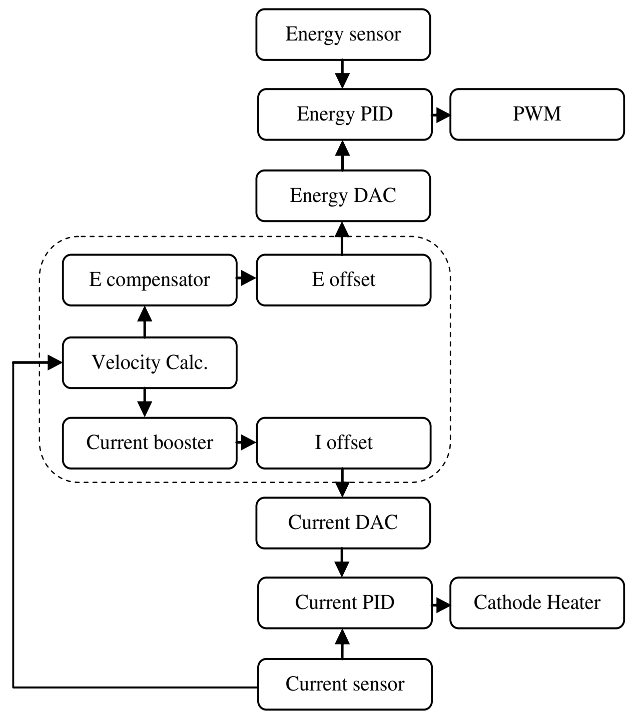

Figure 5: Schematic diagram of stabilization systems.

Third module is current velocity booster. This module controls beam current velocity by generating offset for input of current stabilizer PID. Algorithm keep the velocity in predefined range, for example between 2 mA/sec and 3 mA/sec. If the velocity is not enough, the function will increase the beam current offset, which will be mixed with the current DAC signal. If the velocity is too high, the offset will be decreased. Adjusting this range, we can increase or decrease beam current ascending speed.

RESULTS

Improved stabilization systems provide current velocity up to 5 mA per sec. Modern ELV accelerators can work in a slave mode as part of technology lines with strict requirements to performance and response.

Present system passed through the testing and it is already installed onto ELV-0.5 (0.5MeV 100mA) accelerator in Qingzhou (automobile tire production) and onto ELV-8(2.5MeV 40mA) accelerators in China for cable insulation treatment.

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