

Compensation of input impedance by digital control for high voltage convertor

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Abstract— In this paper, there is presented the digital control of input impedance for high voltage converter. Paper include measurement and evaluation of input impedance performed on auxiliary converter to UIC code 550-2 OR 1st edition and UIC550-3 O, 1st edition standards. The proposed control scheme is created for maximization input impedance for every frequency of injected input voltage.

Keywords— high voltage converter, input injected voltage, digital control, convertor input impedance.

I. INTRODUCTION

The high voltage converters are used like main power supply for devices supplies form high voltage, e.g. train coach, trolley bus, tram and so on. The input voltage is from 800 V to 3500 V in AC voltage and it is from 900 V to 3600 V in DC voltage. The high voltage converter converts voltage from train line in stabilized, DC, galvanic isolated voltage. The chargers, 1f inverters, 3f inverters, electro dynamic brakes are supplied by this voltage. Those devices are used by electric equipment in train or coach. there is a lot of requests for high voltage converter which are defined by norms. One from request is that converter input impedance is higher that minimal value. Minimal value of input frequency is defined by norm UIC550-3. The input impedance is defined as ratio between input voltage, which is injected to DC input voltage, and input current, which is consumed by convertor, on the

same frequency. $Z_i(f) = U_i(f)/I_i(f)$. Norm UIC550-3 define minimal frequency for every frequency of injected input voltage. In figure 1, is shown serial with minimal required input impedance for specific frequency. For example, for input frequency 50 Hz, minimal input impedance is 80 Ω . The digital control has to control high voltage convertor so that input impedance is over minimal required value. For example, the high voltage converter is supply by 1.5 kV DC voltage where 50 V rms, 50Hz voltage is injected. Then, 50 Hz component of input voltage can have maximal 625 mA rms. (80 $\Omega = 50V / 0.625 A$, the value of input impedance can be arbitrary higher). There are many possibilities how increase converter input impedance [1]. Additive inductor is solution, which was used some years before [4]. This solution has many disadvantages. The efficiency of converter is lower because, additive loses are in input inductor and the converter weight increase and desired space for convertor installation increase too. All these disadvantages are main reason, why digital control was developed and used for increase converter input impedance [3]. Digital control change input convertor current flow, so that convertor input impedance is every higher that minimal desired value, see in figure no. 1. As is shown in figure 1, the maximal impedance is desired when frequency of input injected voltage is at zone 1000 Hz, opposite the lowest input impedance is at zone 20 kHz and higher.

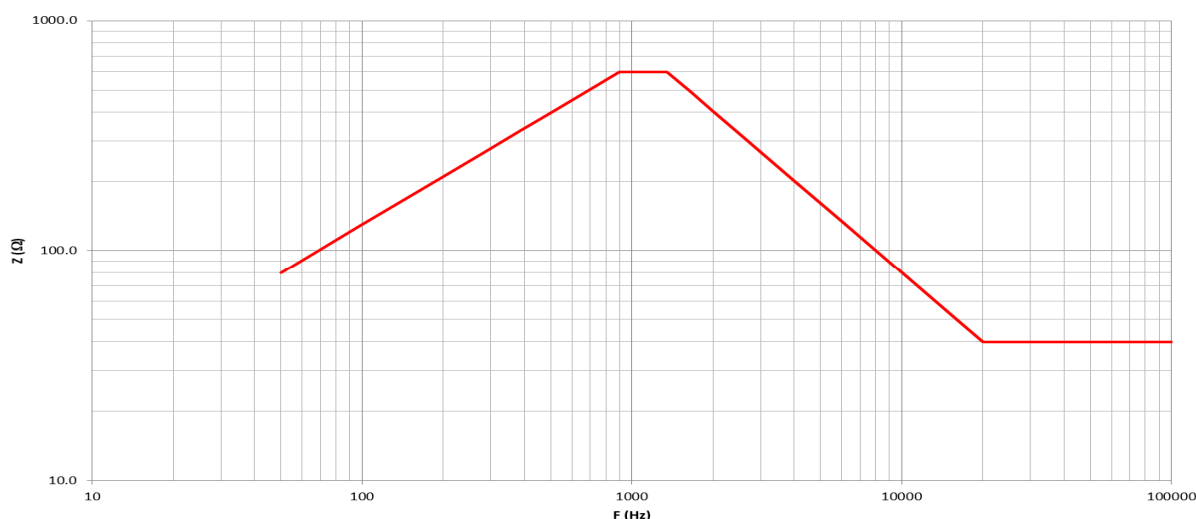


Fig. 1. Input impedance – Minimum values from standard UIC CODE 550-3, 1st edition – Appendix E.

II. THE MEASUREMENT PROCEDURE.

A. Block diagram of measurement

The first at all, we needed to know converter input impedance with standard control algorithm. Measuring

equipment was connected according to block circuit diagram as is shown in figure no. 2 and the list of used measuring devices for measure of input impedance is inserted into following table.

TABLE I. THE LIST OF USED EQUIPMENT

The name of used equipment	Type of used equipment
Rogowski coil 1	Rocoil
Integrator	Rocoil
Transformer (TR)	Prim.: Y3 x 380, Sec.: Y3 x 135
Auxiliary power inverter	SK2-24/230-R1H0
Measure system	SIRIUS-SYSTEM
Notebook	Lenovo Y50-70

For analysis and assessment of input impedance were used following software: SigView, MS Excel, DEWESoftX.

Auxiliary converter was connected to high voltage 1.5 kV DC. Multisystem auxiliary converter for powering auxiliary drives of passenger cars is designed for international transport on European railways. Converter is powered up from the train line with different voltages and frequencies levels and is able to work from all input power voltage which are used on European railways. Output of converter was loaded. Converter was loaded on 50 % of maximal power. It was injected voltage around 50 V on required frequency. As supply of injected voltage was used standalone power inverter see table no. 1, which ensure possibility to change frequency in range 50 Hz – 20 kHz. From measured values of voltage and current was calculated input impedance. The results are shown in figure no. 3.

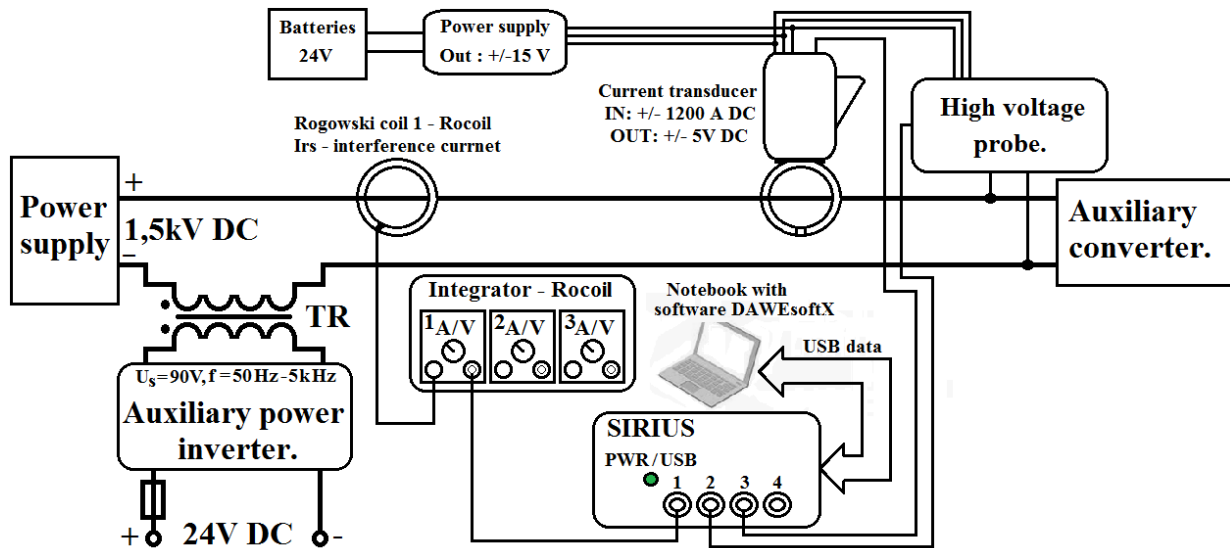


Fig. 2. Block diagram of measuring input impedance.

B. First measurement result.

The first measurement was made on high voltage converter with standard control algorithm (without input impedance compensation, the standard control algorithm is shown in figure 4). The result of this measurement is shown in figure 3. As is shown in figure 3, almost all values a lower that is minimal allowed value. The highest difference is when

desired value of input impedance and measured value is at zone 400 Hz. The digital algorithm with input impedance compensation, has to improve value of input impedance almost for all input frequency. Digital algorithm has to control input converter current flow, that amplitude of consumed current is so that calculate convertor input impedance is in allowed zone, see figure no. 1.

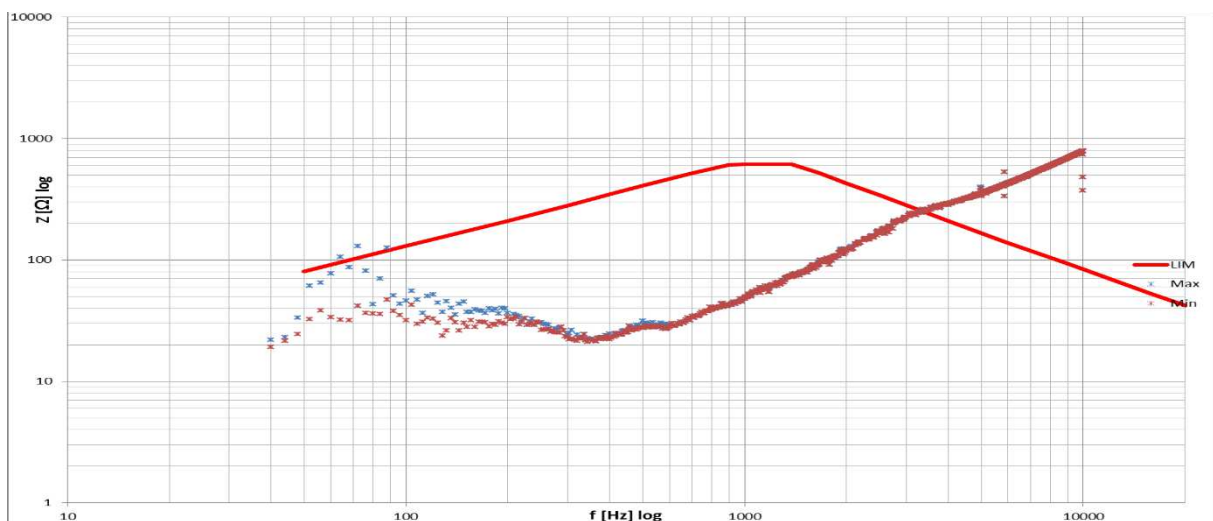


Fig. 3. The result of measurement – standard control algorithm.

III. CONTROL ALGORITHM WITH INPUT IMPEDANCE COMPENSATION.

The standard control algorithm, without any input impedance compensation, has two main regulators unit. The D_shift regulator is the first regulation unit, and the two PI regulators are second regulation unit. D_shift regulator calculates PWM action on base, value on DC bus and input

voltage. Two PI regulators are connected serial. First PI regulator calculate, on the base, required value of DC bus voltage and real value of DC bus voltage amplitude of required input current, second PI regulator calculate on base required input current and real input current output PWM action. Both outputs are counted. The block scheme is shown in figure 4.

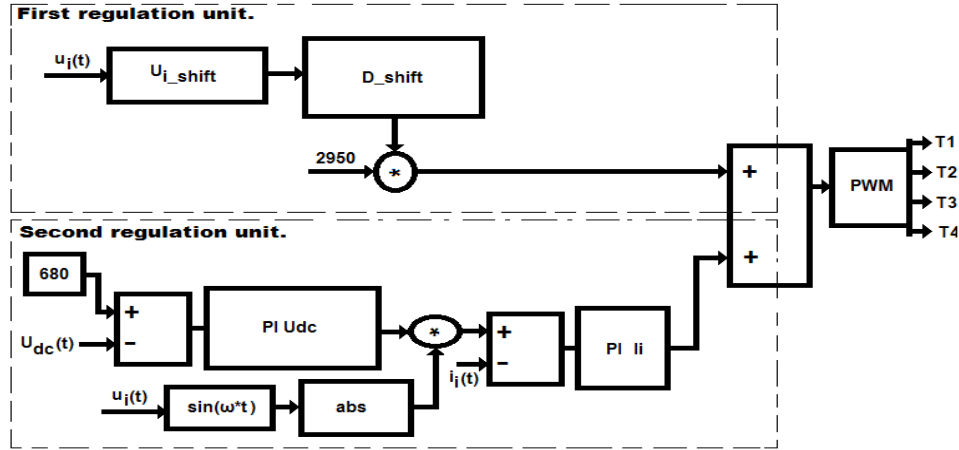


Fig. 4. Standard control algorithm.

The standard control algorithm was modified. The first step was modified block named as U_{i_shift} (see in figure 4). The modification has these main parts:

- Detect and isolate injected signal from input DC power voltage.
- Find frequency and amplitude injected signals.
- Change amplitude and time shift in U_{i_shift} signal (U_{i_shift} – input signal to D_shift controller) on base of input voltage analyze.

The second step is adding controller for AC part of input current. The controller is PI regulator, which change action

signal and try to change AC part of input current to zero level. Similarly, as D-shift regulator, the PI regulator analyze injected part of input voltage, first. The difference between PI regulator and D-shift regulator is that D-shift regulator works when frequency injected voltage is from 40 Hz to 5000 Hz and PI regulator works when frequency injected voltage is from 40 Hz to 700 Hz only. In figure 5, there is shown block scheme of control algorithm, when there is present algorithm for active impedance change. The changes are shown in the figure 5 as the addition regulator divided for two main part. This regulator is active only when DC voltage is present on the converter input and the injected voltage is detected in input power voltage.

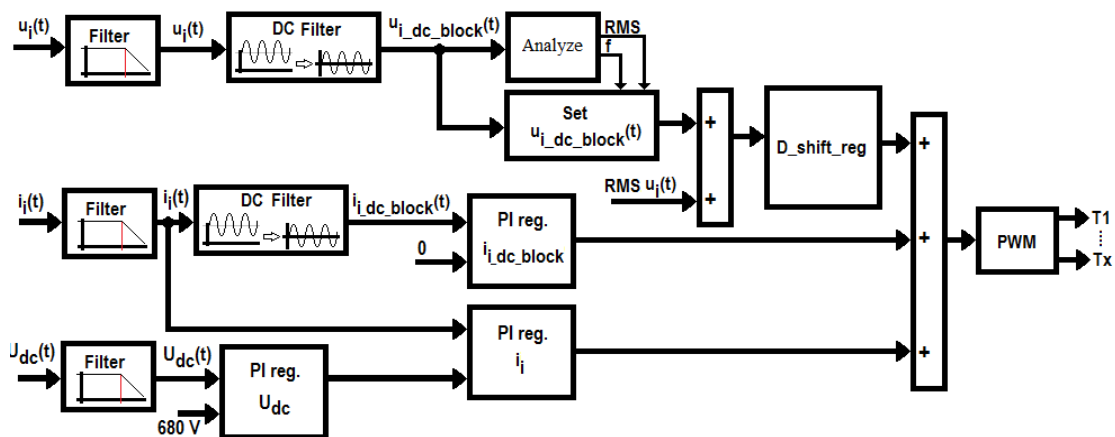


Fig. 5. Control algorithm with input impedance compensation.

The control program changes parameters k_0 (k_0 – gain for injected signal), t -shift (t -shift - time shift for injected signal), k_p (k_p - proportional gain for PI regulator of AC zero part of input current). The right values were got experimentally for every frequency of input injected voltage. The experiments need that input impedance was measured on line and effect of

change every parameter was know immediately. Just one parameter was changed in one time and based on measure result, effect of coefficient change was advised for input impedance. The experiment was finished when input impedance was higher as minimal requested value. In the figure 6, there is shown results.

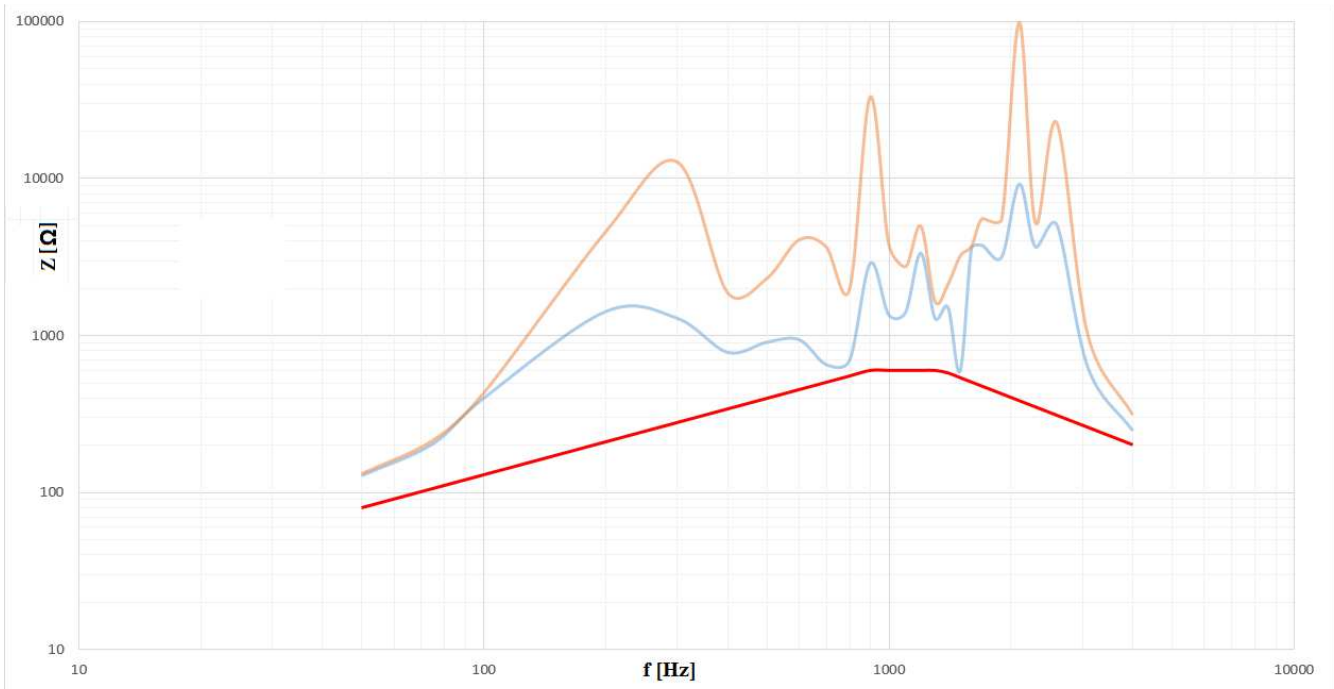


Fig. 6. Final result of input impedance.

The red series is minimal desired value of input impedance defined by norm UIC 550-3. The blue series is minimal value of input impedance which was measured, the orange series is maximal value of input impedance which was measured, both values, minimal and maximal values it measured when the same parameters was set. Dispersion of values was effect of load change. Load change has strong effect for final input impedance for some frequency of input injected signal. All values are over limits, which is desired by norm UIC 550-3 (red series). The highest impedance was measured for injected voltage with frequency 2100 Hz, opposite the lowest impedance was measured for injected voltage with frequency 4000 Hz. All measured was performed with input voltage 1500 V DC.

IV. CONCLUSION

The results presented in previous part in this article shown possibility control input impedance by change of control algorithm without any hardware changes (e.g. increase of input inductor). The changes enabled improve input impedance for every frequency of input injected signal. But, measuring and experiments showed, that final impedance depend on load. The influence of load depends on frequency of input injected signals. Based on experimental measurements performed on auxiliary converter, we have come to the following conclusion with the possibility of modifications to meet the requirements of UIC 550-3, UIC 550-2 (input impedance). Actual hardware solution using additional input inductance is not feasible at that stage and it would require additional HW and SW interventions into an existing configuration. Modifying the input control algorithm shows sufficient results and confirms the possibility of solving the problem by changing the converter software.

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