SIMULATIONS OF 1MVA BRUSHLESS GENERATOR

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Abstract: This project deals with the brushless synchronous generators, is focused on possibilities of rapid de-excitation of 1MVA traction generator. This issue is very important for using this type of generator in rail transport. Standard brushless generator has very poor dynamics which limits its use. In this project is simulated reducing time to de-excite by replacing the diode rectifier for controlled thyristor rectifier.

Keywords: Brushless generator, Simulation, Simplorer

1. INTRODUCTION

Brushless synchronous generators are used for production of electric power wherever the focus is on reliability and low maintenance requirements such as rail and ship transport, backup generators etc. Brushless implementation brings many benefits. This solution eliminates all services of sliding contacts and does not need to use a powerful source of direct current. To energize and control output voltage of 1MVA generator is enough power less than 100W. So far, the best way to bring the DC current to the rotor of main machine is rotating exciter (Figure 1).

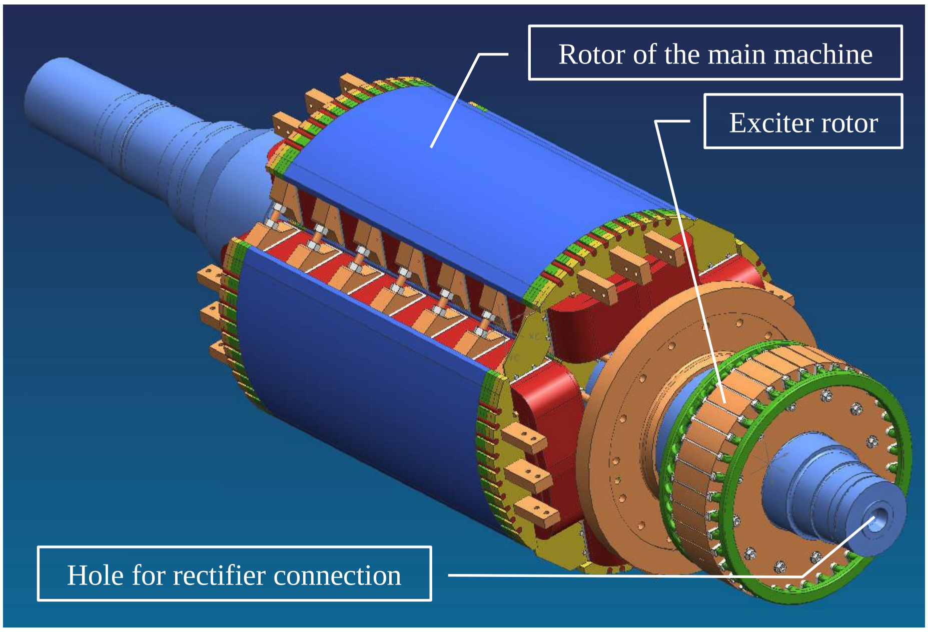

Figure 1: Exciter rotor located on common shaft with the rotor of main machine [1]

Rotating exciter is designed that the stationary part of the exciting coil is fixed to the stator structure of the main machine, while the 3-phase rotor winding is located on the shaft. Exciter stator and rotor is forming a separate synchronous machine with the opposite arrangement compared to the main synchronous generator. Exciter rotor winding energize the rotor of main machine. Since the output of exciter is 3-phase AC current, it is necessary to rectify it first with rectifier mounted on the shaft. Main disadvantage of this arrangement is poor dynamic of control output voltage [2], [3]. Excitation winding in generator has enormous inductance and in magnetic field is stored a lot of energy, which cannot be quickly exhausted. The aim of this paper is to examine effective solution to the fast de-excitation of the brushless generator and thus suppress its major disadvantage.

1.1. NECESSITY FOR RAPID DE-EXCITATION

Modeled generator is used as an energy source for many diesel-electric locomotives. Generator through the rectifier energizes the serial excited DC traction motors. The locomotive is also equipped with an electromagnetic brake. This is such a condition of the vehicle, when train moves a certain speed and traction motors works in generator mode and train kinetic energy is transformed into electrical energy. To switch from driving mode to electromagnetic braking must be output voltage of the generator close to zero (de-excited rotor winding), then electric traction circuit has to be switched to braking mode (in electrodynamics braking mode traction motors has to realign to shunt connecting DC motors) and then re-energize the traction generator to the desired value. This whole process should run through due to safety and controllability of the locomotive as quickly as possible. Therefore it is necessary to explore possibilities of rapid de-excitation. Generator nominal values are shown in Table 1.

Name	Description	Value
S_n	Output Power	1000KVA
U_n	Output Voltage	407V
I_n	Current	1419A
f_n	Frequency	90Hz
n_n	Rotor Speed	1800min^{-1}

Table 1: Nominal data of synchronous generator

2. MODEL OF BRUSHLESS GENERATOR

The model is created using Simplorer program, which includes a rich library of blocks for the simulation of multi-domain systems. The brushless generator model consists of two separate synchronous machines on a common shaft and on the outputs are 6-pulse rectifiers. As the load is used RL circuit to simulated nominal generator load. Model Parameters are shown in Table 2.

2.1. EQUATIONS OF SYNCHRONOUS MACHINE

In synchronous machines all flux-linkages, voltages, and currents are function of rotor angle. Therefore, is the better way to transform machine equation to coordinate system bound to the rotor (d-q) to speed up the calculation [4].

Voltage equation:

$$v_{1d}(t) = i_d(t)\cdot R_1 + \frac{d\Psi_{1d}(t)}{dt} - p\cdot\omega(t)\cdot\Psi_{1q}(t) \tag{1}$$

$$v_{1q}(t) = i_q(t)\cdot R_1 + \frac{d\Psi_{1q}(t)}{dt} + p\cdot\omega(t)\cdot\Psi_{1d}(t) \tag{2}$$

$$v_{ed}(t) = i_{ed}(t)\cdot R_e + \frac{d\Psi_{ed}(t)}{dt} \tag{3}$$

Flux-linkage equation:

$$\Psi_{1d}(t) = i_d(t) \cdot L_{1d} + i_{ed}(t) \cdot L_{m1ed} \tag{4}$$

$$\Psi_{1q}(t) = i_q(t) \cdot L_{1q} \tag{5}$$

$$\Psi_{ed}(t) = i_d(t) \cdot L_{m1ed} + i_{ed}(t) \cdot L_e \tag{6}$$

Where v_{1d}, v_{1q}, v_{ed}, i_d, i_q, i_{ed}, Ψ_{1d} , Ψ_{1q} , Ψ_{1ed} are voltages, currents and flux-linkages in d-q axis and excitation winding.

Name	Description	Exciter Value	Generator Value
R_1	Stator Resistance	24.8mΩ	2.29mΩ
L_{1d}	Stator Inductance d-axis	0.868mH	1.195mH
L_{1q}	Stator Inductance q-axis	0.458mH	0.621mH
L_{m1ed}	Mutual Inductance stator-exciter d-axis	13.93mH	66.45mH
R_e	Excitation Resistance	4.02Ω	1.65Ω
L_e	Excitation Inductance d-axis	643mH	6.017H
p	Number of Pole Pairs	6	3

Table 2: Parameters of the Exciter and the Generator

3. SIMULATIONS RESULTS

The waveforms show the important electrical parameters at full excitation and de-excitation. At the time 6s excitation voltage drops to zero and the generator starts to de-excite. After about 0,8s excitation current drops to zero as shown in figure 2.

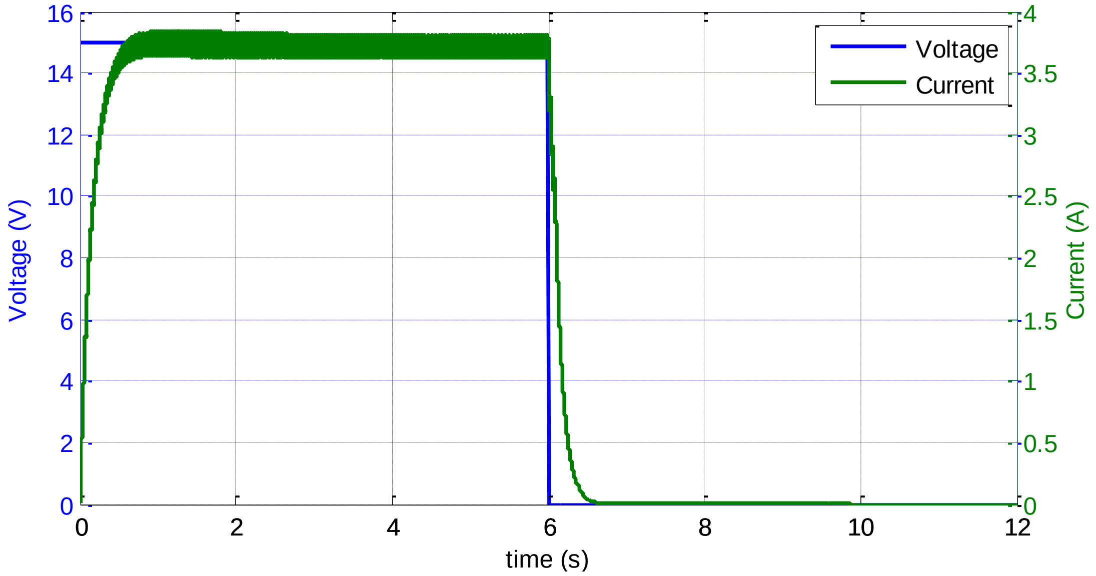

Figure 2: Excitation voltage and current of exciter

Figure 3 shows the output voltage of the exciter and current in main excitation winding. It can be seen that after voltage drops to zero current in the excitation winding flows 6 more seconds. This situation is very negative, because the train could not use electrodynamic brake before this time. Replacement commonly used diode rectifier for controlled thyristor rectifier would make it possible to change the polarity of the excitation voltage, which could termination of excitation current greatly accelerate. This solution is inspired by United States Patent [5].

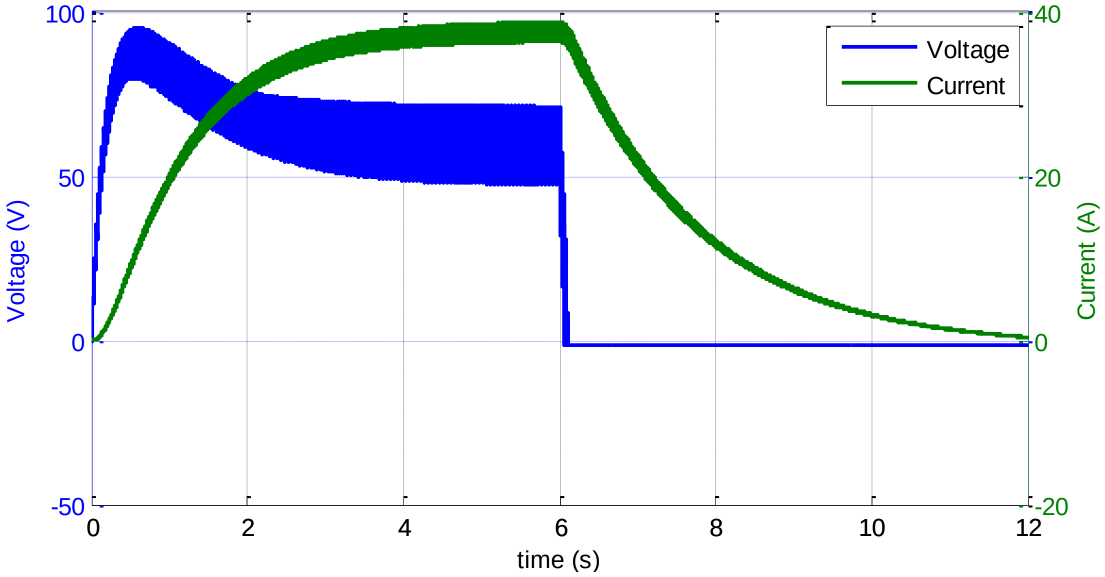

Figure 3: Excitation voltage and current of the main machine

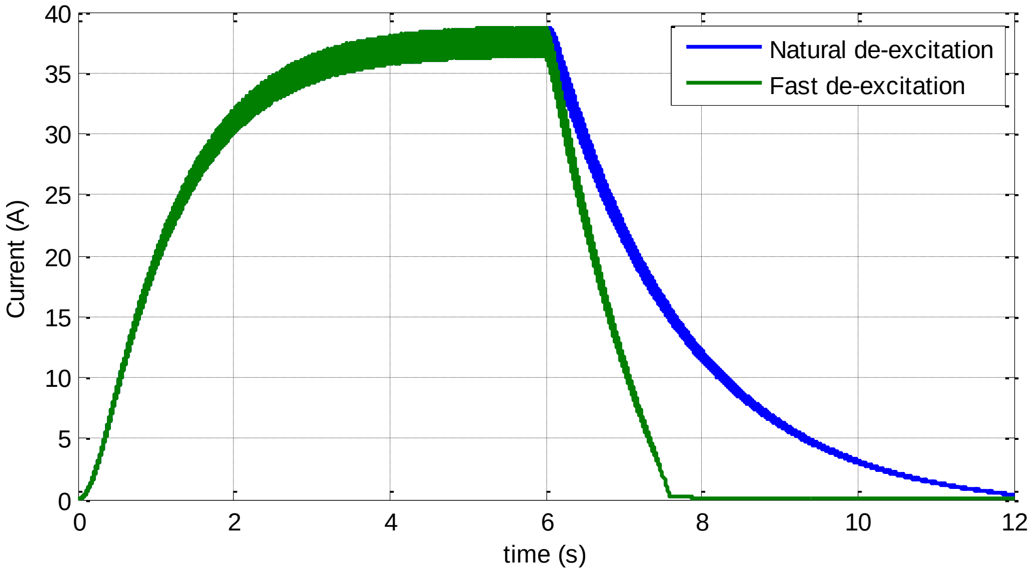

Figure 4: Comparison of the generator excitation currents

As shown in figure 4, the time required to termination of excitation current is reduced to less than one third. This current directly corresponds to the output voltage of the generator as shown in figure 5.

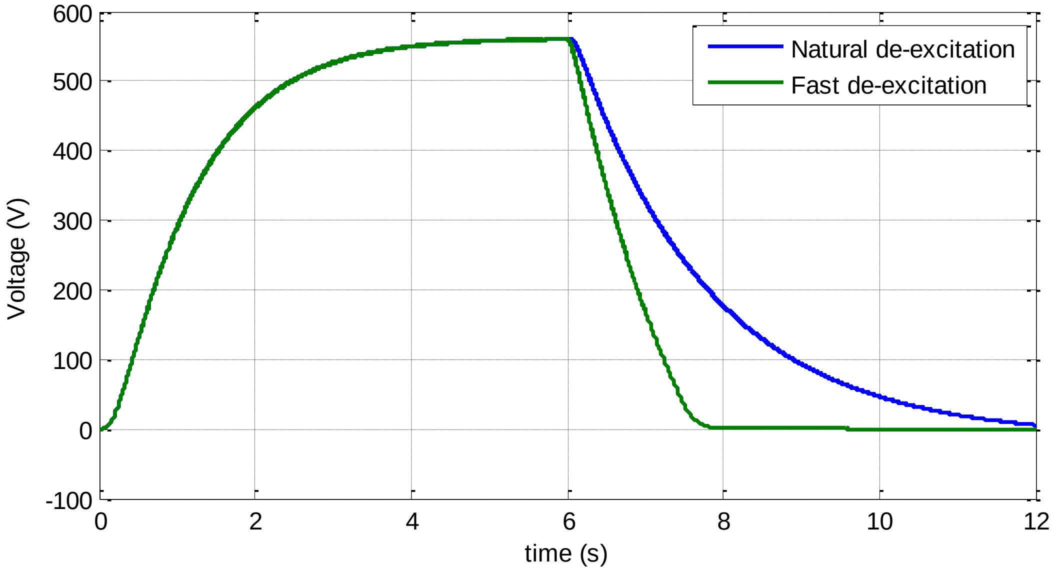

Figure 5: Comparison of the generator output voltages

4. CONCLUSION

By replacing the diode rectifier for controlled thyristor rectifier can be achieved significantly faster field weakening. With this design it is possible to use electrodynamic brake more efficient. Unfortunately, this solution does not take place without interference in the internal arrangement of the generator and brings other technical problems. Currently are examined other possibilities of rapid de-excitation with the emphasis on the simplest design.

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