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Application of Electric Springs for Reactive Power Compensation on Load Side

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ABSTRACT

The use of renewable energy sources is gaining a vital role in the recent years. But due to their intermittent nature, they cause disturbance or voltage fluctuations. The simple control of electric spring is a new smart grid technology for mitigating variations caused by renewable energy sources. The stabilization of the voltage at the load side is the main aim which can be obtained through electric springs. The simulation results built by MATLAB/SIMULINK show the voltage waveform on power grids with or without electric spring.

Keywords: Electric Spring, Power Grid, Critical Loads, Reactive Power Compensation.

I. INTRODUCTION

The increasing awareness about climatic changes has let the Governments worldwide to call for the implementation of renewable energy sources. Renewable energy sources have many advantages for environment and the society by providing energy security. The wind, solar power have become the pillars of energy systems and they are more reliable and affordable sources of electricity. Many countries have proposed increasing renewable energy power plant's share in future power systems. The effect of renewable energy sources due to their intermittent nature is the destabilization of electric grids, causing potential blackouts and damage to the critical loads. Hence the power quality problems arise in the power systems. The load management, where load demand follows power generation is the main concern. Electric spring, which is based on power electronics technology can control the voltage fluctuations caused by the renewable energy sources without any need for communication. It is autonomous (no need for centralized control systems). Thus it can be distributed over the power grids (Eg.: Households, industrial sites etc.) to stabilize the supply voltage in real-time. Although it is a small power devices, many "small" but distributed electric springs provide a collectivelyrobust stabilizing effect. In future power systems where renewable energy sources will be connected to the power grids in a distributed manner, decentralized power compensators in numerous small capacities at the load side can be more favorable than the centralized approach. Thus the electric springs help to achieve voltage stability and power compensation.

II. PRINCIPLE OF ELECTRIC SPRING

Electric spring has the similar operational functions as that of the mechanical springs. As mechanical spring is an elastic device that provides mechanical support, store mechanical energy and damp mechanical oscillations. Analogous to a mechanical spring, an electric spring is an electric device that can be used to provide electric voltage support, store electric energy and damp electric oscillations. Efficient integrated approach for voltage control and aggregated demand action can be achieved by categorizing loads into critical loads requiring constant voltage and non-critical loads. Electric spring, a new smart grid technology is the reactive power controller of input voltage control instead of the traditional output voltage control. It is a power electronics technology which can stabilize the voltage of critical load, through modulating the voltage of non-critical load. Critical loads like medical and sophisticated loads are sensitive to the change of voltage are connected to the power grid directly. They require constant and reliable power supply (power quality). Non-critical loads like water heaters, lighting system, fan loads etc. tolerate the fluctuations in voltage to certain extent without causing much inconvenience to the consumers. The non-critical loads are connected in series with electric spring. For stabilizing the voltage of critical loads, electric spring injects the compensated voltage to the coupling point of critical load and power grid. The block diagram of the network is shown in Figure 1.

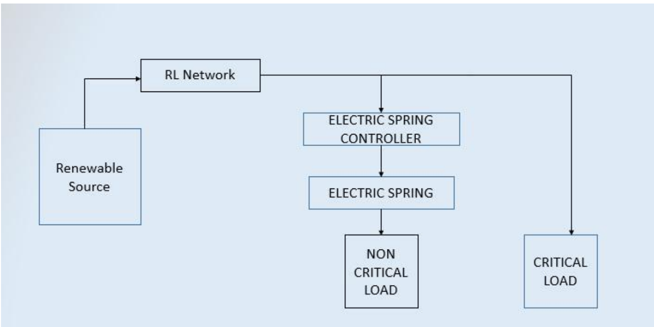


Figure 1

III. ELECTRIC SPRING OPERATION AND REALIZATION

Electric spring can be realized through the full bridge inverter shown in Figure 2.

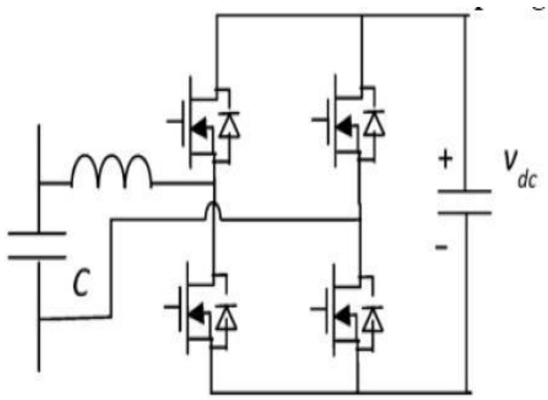
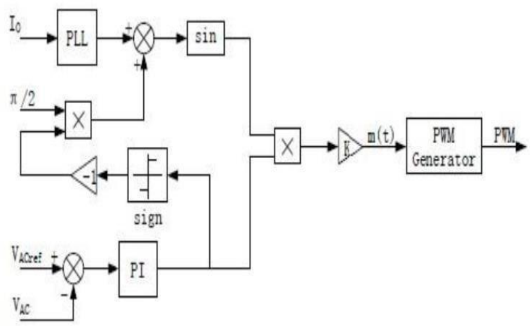


Figure 2

The full bridge inverter reduces switching currents and helps in attaining maximum voltage twice that of half bridge topology. The LC filter connected across the AC side helps in keeping the output voltage of electric spring as the sinusoidal wave. The electric spring controller consists of the PLL, PI controller and the PWM generator as shown in Figure 3.



The PLL (Phase locked Loop) tracks the phase angle and the frequency of the sinusoidal signal. The PI controller always sets the error voltage to be less based on the reference voltage. The PWM generator generates the pulses and the output is given to the electric spring, which comprises of Inverter, storage components Lf and Cf, which also act as filters an RCD snubber circuit to prevent the main circuit to resonate effectively. The pulses from the electric spring controller when fed to the electric spring, the inverter operation takes place which leads to injection of the voltage to the coupling point of the critical load and power grid.

IV. SIMULATION OF ELECTRIC SPRING

The simulation of overall network is shown in Fig.4. The frequency of the network is 50 Hz. The resistance and inductance of the lines are taken as 0.1 ohm and 2.5 mH respectively. The non-critical load resistance is 35 ohm and critical load resistance is 85 ohm respectively. The AC supply from renewable energy source is given with a disturbance to the line. After the operation of electric spring, the waveforms of voltage across critical load without and with electric spring are shown in Figure 5 and Figure 6 respectively.

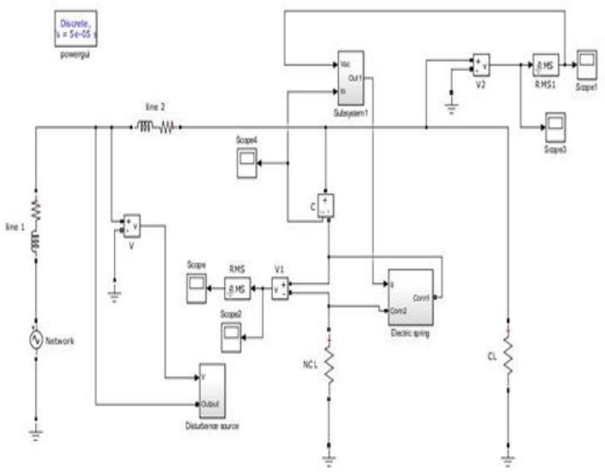


Figure 4

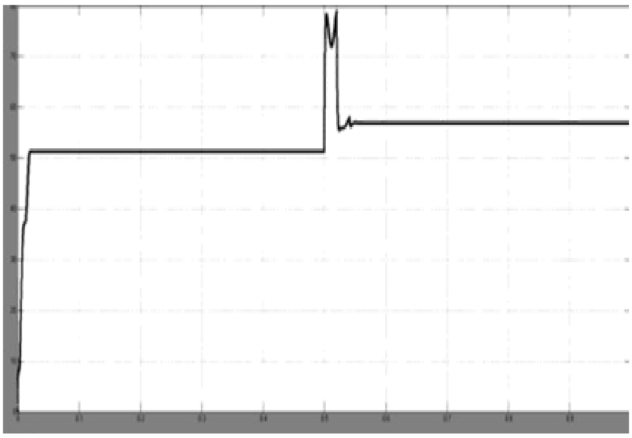


Figure 5. Critical Load voltage without Electric Spring

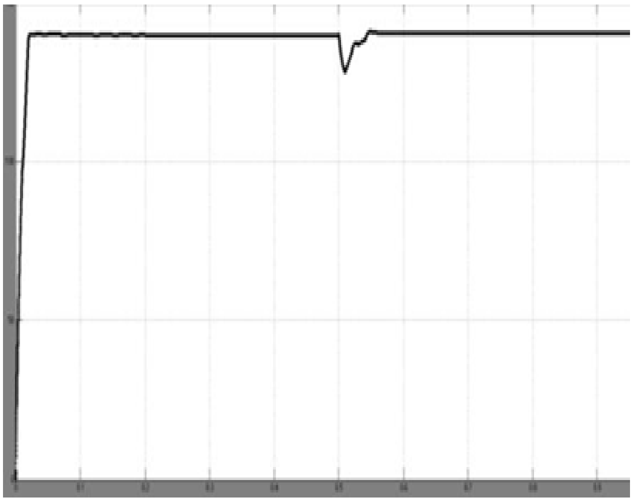


Figure 6 . Critical Load voltage with Electric Spring

V. CONCLUSION

The new smart-grid technology for the load side management is proposed to tame the intermittent nature of renewable energy sources which causes power quality problem in power systems. The simulation of electric spring successfully shows the stabilization of voltage across the critical load. The results confirm that electric spring can be incorporated in the future power systems with renewable energy sources to perform voltage regulation and power balancing.

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