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# DC Electric Spring for Microgrids

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**Abstract:** A lot of emphasis is being made on integrating renewable energy sources like solar energy, wind energy into DC distributed power system and DC micro grids. When large proportion of power is being generated from renewable energy sources, there will be power quality and grid stability issues. This paper presents an electric active suspension technology known as the DC electric springs for stabilizing and improving the quality of the power distributions in DC microgrids. DC electric spring can be used for (i) regulating the DC bus voltage within the required limits while enduring the fluctuations of intermittent energy sources or deep voltage sags of power faults and (ii) performing load boosting and shedding functions to match the power consumption of the DC loads to the renewable power generation connected to the DC grids. Simulations results show that the above conditions can be achieved in the DC microgrids and the quality issues can also be mitigated using the proposed DC electric spring technology.

**Keywords-**Smart load, distributed power systems, power electronics, electric springs(ES), DC grids, smart grid**.**

## I. INTRODUCTION

Renewable energy has several benefits such as positive impact on the environment, benefits to the society, increases energy security. Whereas fossil fuels contribute to climate change and it is a finite resource and will eventually run out. Solar power installations are growing more than 40 percent annually, and falling PV prices are making solar power more affordable. Germany added more than 7000 megawatts of PV. In Australia, one in 5 homes is solar-powered. Residential rooftops host the majority of its 2400 megawatts. The largest share of those new turbines went up in the United States and China, each of which added an estimated 13000 MW of capacity. In total, 46 countries added wind power to their grids in 2012, according to the report, accounting for $75 billion in spending. Without doubt, wind and solar power have become the pillars of the energy systems in many countries and they are recognized as reliable and affordable sources of electricity.

Many countries are phasing out its nuclear plants in favour of wind and solar energy backed-up by coal power. The transition to these intermittent green energy technologies is causing a lot of problem with its electric grid. The intermittent power is causing destabilization of the electric grids causing potential blackouts, weakening voltage and causing damage to industrial equipment. The instability of the electric grid is just one of many issues that the companies are facing regarding its move to intermittent renewable technologies. The power network needs to accommodate significant variable renewable energy and maintain stability, efficiency and security.

### A. The Destabilization Problem

With many countries worldwide determined to decarbonise electric power generation within the next few decades, new concerns about power system stability have arisen from the increasing use of intermittent renewable energy sources. Wind and solar technologies are volatile supply of power. Not only may a scarcity of electricity result in a power blackout, but an oversupply can also lead to grid instabilities as they alter the frequency (& voltage) within the network. The intermittent power is causing destabilization electric grids, causing potential blackouts, weakening voltage and causing damage to industrial equipment. Injection of intermittent power through grid connected power inverters, without considering power system stability, is destabilizing the power systems.

Wind turbines which have large generating capacity regularly overload the electricity grid, threatening blackouts. The situation tends to be particularly critical on public holidays when residents and companies consume significantly less electricity than usual with the wind blowing regardless of the demand and supplying electricity that isn't needed. In some extreme cases, the region produces three to four times the total amount of electricity actually being consumed, placing a strain on the electric grid. Short interruptions increases and the number of service failures occur resulting in failures leading to production stoppages causing large scale damages. These power grid fluctuations are causing major damage to a number of industrial companies, who have responded by getting their own power generators and regulators to help minimize the risks.

The existing control paradigm of power systems is to generate power to meet the load demand, i.e., "power generation following load demand". With the increasing use of intermittent renewable energy sources, known or unknown to the utility companies, it is impossible to determine the instantaneous total power generation in real time. In order to achieve balance of power supply and demand, which is an essential factor for power system stability, the control paradigm for future smart grid has to be shifted to "load demand following power generation". Various load demand management methods have previously been proposed. Some examples include load scheduling, use of energy storage as a buffer, electricity pricing, direct control or on-off control of smart loads etc.

Based on the three-century old Hooke's law for mechanical springs, electric springs (ESs) have recently been proposed and successfully developed as a new smart grid technology for stability control in power grid and for achieving the new control paradigm of load demand following power generation.

## II. DC MICROGRID

A DC microgrid comprises of DC power generation (i.e. fuel cell, solar PV panels, or micro wind turbines), DC electrical storage (i.e. battery or super capacitor), DC power distribution (i.e. wiring and control) , DC gadgets (i.e. laptops, telephones, satellite TV controllers) ,DC lighting (i.e. LEDs). Whilst homes generally require an AC supply for inherently "high" power devices such as washing machines, kettles and hairdryers, there are a surprising number of environments, such as site offices and outdoor events, where these devices are not used. In such cases a DC microgrid could be the sole power provider. The elimination of inverter cost, simplified installation and reduced fuel costs yielded by a DC microgrid system potentially make it cost effective to operate independently of the electricity grid and conventional mains-power generators. The conventional electrical system in place today sees our electrical devices powered by AC mains. But as renewable technologies such as solar photovoltaic's and wind power become more prevalent at a household level, DC microgrids could be a cheaper and more efficient alternative. Take lighting and 'gadgets' for example. Lighting is widely considered to account for around 20% of global electricity consumption, and a recent report from the International Energy Agency estimates that up to 15% of domestic energy is consumed through 'gadgets' - i.e. computers and consumer electronics. LEDs are emerging as a preferred option for high efficiency lighting, and they run on DC power. Similarly, most gadgets operate on DC power, so these two sectors alone add significant and increasing global consumption of electricity by DC devices. But these are presently powered by AC mains via multitudinous individual transformers.

 

**B.Feasibility of DC Microgrids**

Fuel cells and much small scale renewable natively generate low voltage DC power. Most of these generators supply power to AC mains networks and require costly and inefficient power invertors; even where the power may ultimately be delivered to a DC device. A possible solution is to install a DC network linking DC devices to DC power supplies. Such networks have not yet emerged because of the higher electrical losses associated with transmitting a fixed amount of power as low voltage DC, rather than higher voltage AC. But with the proliferation of low power electronic devices, bringing the potential for LEDs to reduce lighting loads by a up to a factor of 10 and the potential for efficient distributed power generation, localised DC networks – or DC microgrids - may finally be practical. Aside from reducing resource and financial costs, a key advantage of DC microgrids is that the low risk of dangerous electric shocks from low voltage DC makes plug-and-play grids a possibility. This greatly reduces the installation cost of micro-generation, and could empower end users to take responsibility for understanding and controlling their individual energy consumption. Adding intelligence and internet connectivity to DC micro-grid controllers further enables consumer engagement with AC mains devices - through smart metering and ultimately with dynamic demand management. And this could reduce costs associated with periods of high and low power consumption.

## III. ELECTRIC SPRING

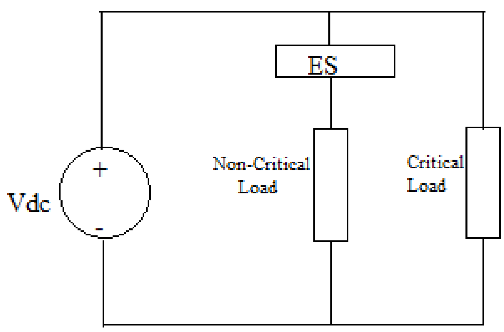


***Fig 1.General Block Diagram of DC-Electric Spring***

Power electronics, being an enabling technology, can offer new solutions to the stability control of future DC microgrid with substantial penetration of distributed and intermittent renewable energy generation. Power generated from renewable energy sources need to be controlled for it to be used by electronic devices connected to the grid. If excess energy is produced it may damage the devices and if deficient amount of energy is produced it may cause low voltage problems. Electric spring is a device which performs power boosting and shedding operation in order to match with load power. Devices connected in the grid are usually classified into critical and non critical loads. Critical load are given more importance the main function of the electric spring are to make sure continuous and seamless power supply to these devices. Electric spring consist of bidirectional converter connected to a series of battery. These batteries and converters are controlled by a controller which is used to perform boosting or shedding operations according to availability of power from the energy sources or follow load demand

## IV. OPERATING PRINCIPLE OF ELECTRIC SPRING

In order to understand the working and advantages of the electric spring in this paper we are going to simulate a Dc-microgrid connected to a PV array. Two simulations are done, one with ES and one without ES. The ES is connected in series with the non-critical load and critical load is connected in parallel with ES. We have set the reference Dc voltage as 19V. Once power is being generated by the PV array it is fed in to microgrid and used by the loads. In the grid without ES, the power generated by the grid is 24V. Once the power consumption is increased by the loads the voltage drops to 19V which is equal to load voltage. But when the load voltage increases the voltages drops below the reference voltage. These shortcomings can be overcome with the use of ES. The ES designed here has two batteries, one designed for charging during the presence of excess power and another discharging during power deficiency.

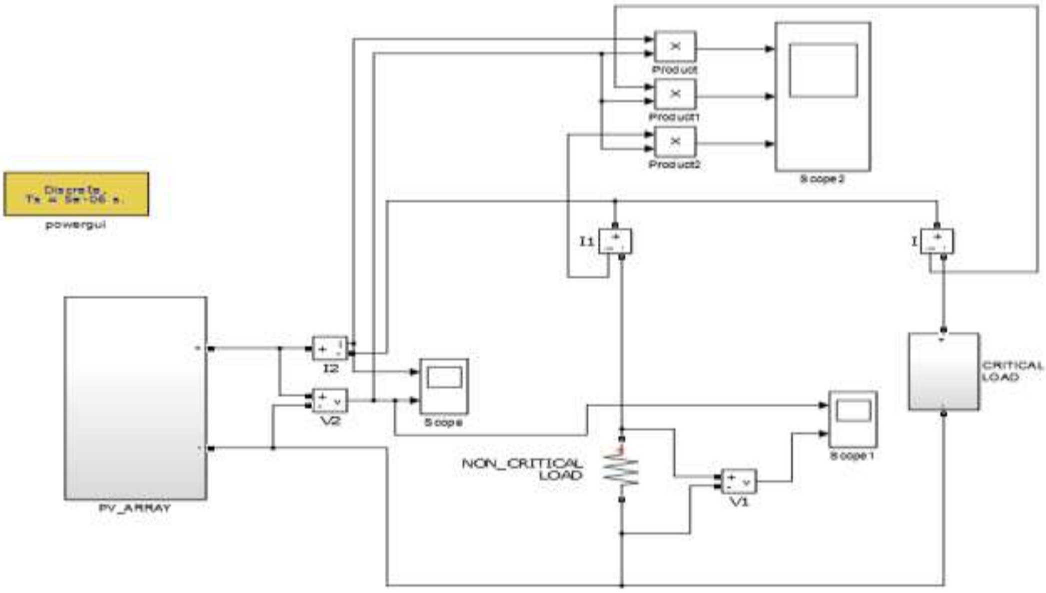


*Fig 2. Experimental Setup in Simulink without Electric Spring*

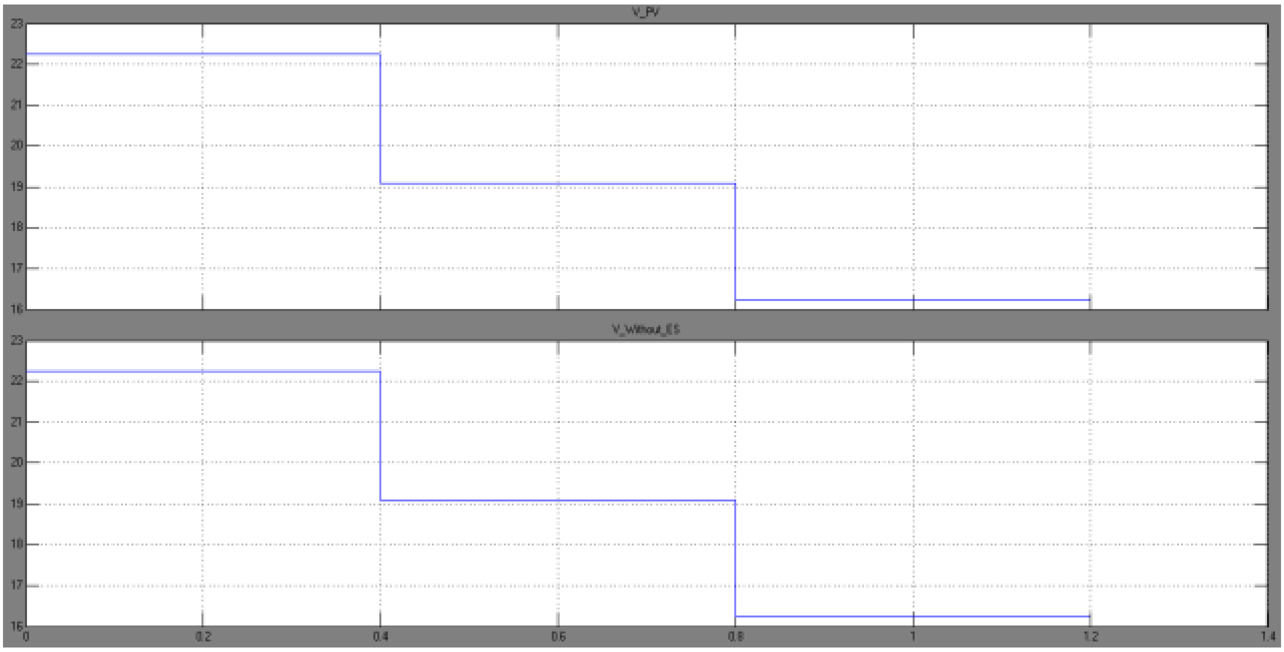


*Fig 3. Experimental result without electric spring with a constant-resistive non-critical load*

For microgrid without ES the graph shows that the voltage across the decreases as the load resistance increases. This causes the load voltage to drop below the reference voltage(19V).This type of situation can be avoided using ES.

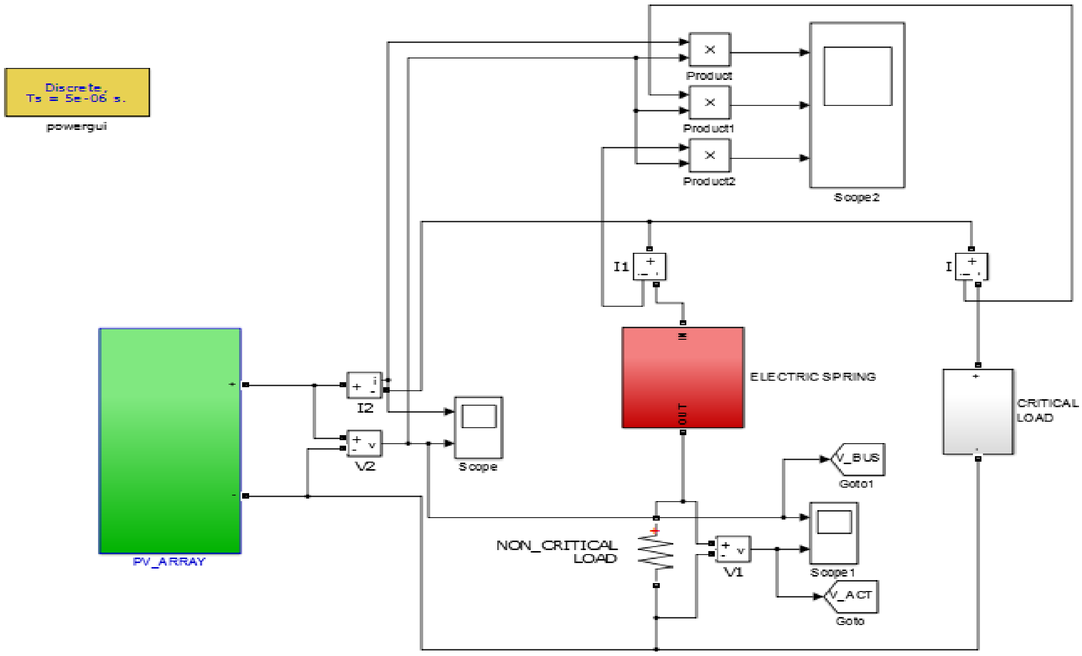


*Fig 4. Experimental Setup in Simulink with Electric Spring*

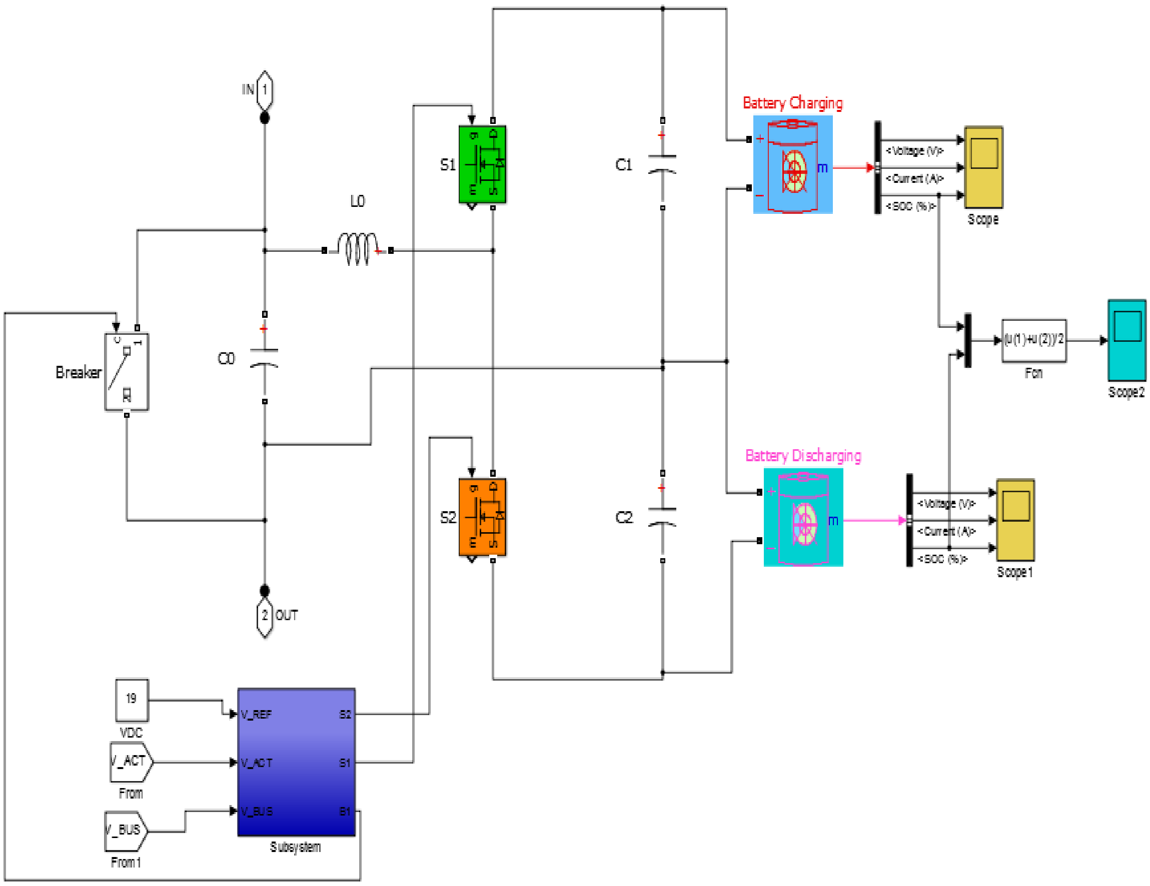


*Fig 5 .Inside Structure of an electric Spring*

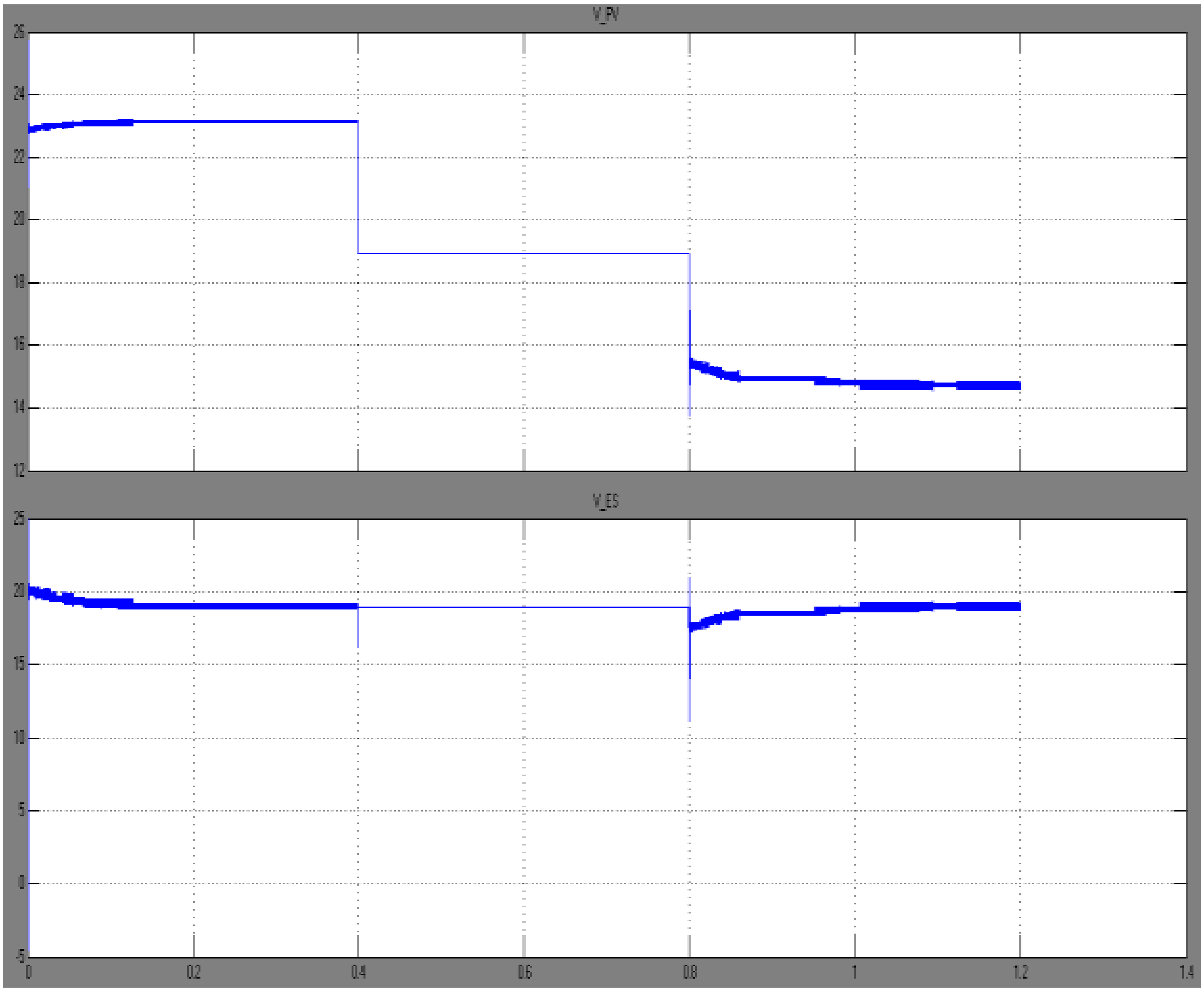


*Fig 6. Experimental result with Electric spring and a constant-resistive non-critical load*

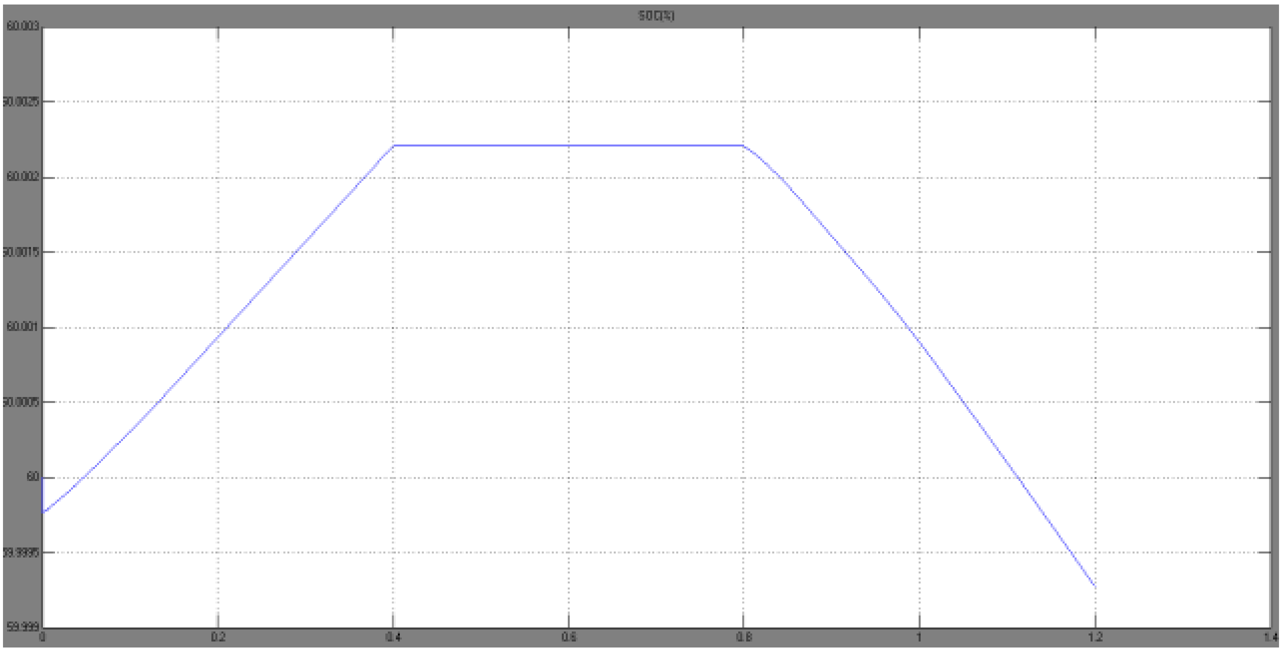

*Fig 7. State of charging for the two batteries connected.*

The microgrid with the electric spring show that the graph where the output voltage is almost and always maintained near the 19V mark. Thus from the above graph it can be easily seen than ES can help maintain the voltage stability of a DC microgrid.

## V. CONCLUSION

The above experimental setup shoes that electric spring for microgrids connected to renewable energy sources can be used as a voltage stabilizer. With AC-DC conversions not required in the DC microgrid, harmonics can be eliminated. With the development of power electronics DC microgrids will become more common and electric spring will be used even more in stabilizing DC microgrids.

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