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Utilizing The Smes Dynamic Voltage Restorer To Compensate For Voltage Sag And Swell

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Abstract
SMES has incredibly effective energy storage (conducting magnetic energy storage). To increase the power grid's brilliant intensity, it depends on its quick response time and power controllability. SMES invention has the potential to provide genuine power storage trademarks, high voltage, and thickness for quick reaction. Customers were safeguarded by this SMES standard from sag, swell, and interference-causing network voltage changes. This work examines the SMES-based DVR's activity rules. The DVR uses a straightforward PI control method to resist voltage droops, swells, and incursion. Using SIMULINK or MATLAB, the models of the SMES-based DVR are built, and simulation tests are done to assess grid disruptions.

Keywords: swell, incursion, voltage, restorer, MATLAB, power storage

1. Introduction

The majority of the inquiries on SMES for improving power quality use two different approaches. One is securing delicate responsibilities by using SMES as an UPS. Full power for the heap must be paid for by the SMES-UPS, which necessitates large limit converters and energy storage devices. The parallel compensation is accomplished by controlling the current on the SMES coil. Power systems have seen positive advancements in the production, transmission, and distribution of electric power.Energy storage technologies offer significant advantages for enhancing supply reliability, power quality, and stability. To satisfy the demands of realistic power system applications, storage technologies have advanced dramatically [1]. As electrical traffic and electricity transaction rates increase in a densely connected network, the operation of the power system becomes more challenging and unsafe. Engineers working on difficult power systems are searching for more adaptable and controllable ways to run the system. [9]. As a result, more resource utilisation is permitted, encouraging the uptake of renewable energy sources and improving the performance and stability of the net [3]. The microgrid, which consists of distributed photovoltaic generation, energy storage, and loads, is analysed in detail with reference to the effects of the SFCL and the DVR. Additionally, a related theoretical analysis, simulation study, and economic assessment are carried out [2]. Tension quality and frequency quality are the two subcategories of power quality issues. Problems with frequency performance are related to harmonics and transients, whereas issues with voltage quality are related to voltage drop, swell, drop, and drop[5]. The voltage drop that occurs when voltage-sensitive equipment is used is one of the most important problems with power quality. The steady state performance of both DVR and D-STATCOM is computed and compared for various voltage sag, system failure level, and load levels [4]. As a result, supply voltage sags are now more likely to affect industrial activities.Table 1 provides the normal voltage correction for sag and swell.

Disturbance	Voltage (PU)	Duration
Voltage Sag	0.2 – 1.9 p.u.	0.5 – 30 Cycles
Voltage Swell	1.3 – 2.5 p.u.	0.5 – 30 Cycles

Devices for long-term energy storage include batteries, redox flow, hydrogen fuel cells, and compressed air. Flywheels and super capacitors can't be used for applications requiring short bursts of high power since they have low power and energy ratings [5]. A transmission line can use an energy storage device to increase the compensation's effectiveness.he suggested device is known as DVR FCB (Fuel CellBased) offers a flexible and modular system architecture;It can be integrated with conventional DVR systems. Further, theSystem features can be changed in terms of their strength and dependabilityand adjustment for voltage sag [6].

2. ENERGY STORAGE UNITS

Energy storage systems can be divided into 2 categories: indirect and direct energy storage.

1. Limited groups (10MW): flywheel batteries and ultra-capacitors are available in small categories when used in conjunction with DG devices.
2. Medium categories (10MW to 100MW energy): These categories include lead acid, NAS, large-scale batteries, and redox.

Equation provides the storage devices' efficiency (1). Regarding storage capacity and discharge time, Table.2 lists the applications for energy storage. Table.3 lists a few variables.

Table 2: Grouping of stored capacity

Application	Stored Capacity	Discharge Period
Power Grid Leveling	11 MJ-201 GJ	Few Sec. - Few Days
Power Quality	0.11-11 MJ	Few Sec.
Custom Devices	0.11-11 MJ	Few Cycle

Table 3: variables of energy sorage capacity

S. No.	Technology	Efficiency %	Energy Density [W-h/kg]	Power Density [kW/kg]	Sizes [MW-h]
1.	Pumped hydro	75	.27/100 m	Low	5000-20000
2.	Compressed gas	70	0	Low	250-2200
3.	SMES	90 +	0	high	20 MW
4.	Batteries	74-84	30-50	0.2-0.4	17- 40
5.	Flywheels	90 +	15-30	1-3	0.1-20 kwh
6.	Ultra capacitors	90 +	2-10	high	0.1-0.5 kwh
7.	Fuel cell	<70	300-600	1.06-2.50	250 mwh

As demonstrated in Table 4 below, response capacity has been and continues to be employed in a variety of ways at all levels of electric power networks.

Table 4: Characteristic SMES Application

Field	Application	Discharge time required
Generation	Load Leveling	Hours
	Dynamic Response	Hours
	Spinning Reserve	Minutes
	Frequency Control	Seconds
Transmission	Load Leveling	Minutes/Hours
	Stabilization	Seconds
	Voltage/VAR Control	Cycles
Distribution	Load Leveling	Minutes/Hours
	Power Quality	Seconds
	Custom Power	Cycles

3. SMES WITH DVR

Figure 1 depicts the fundamental design of a DVR with super magnetic energy storage. It has a capacitor bank, voltage injection transducer, low- pass filter, magnetic energy storage, and VSI.

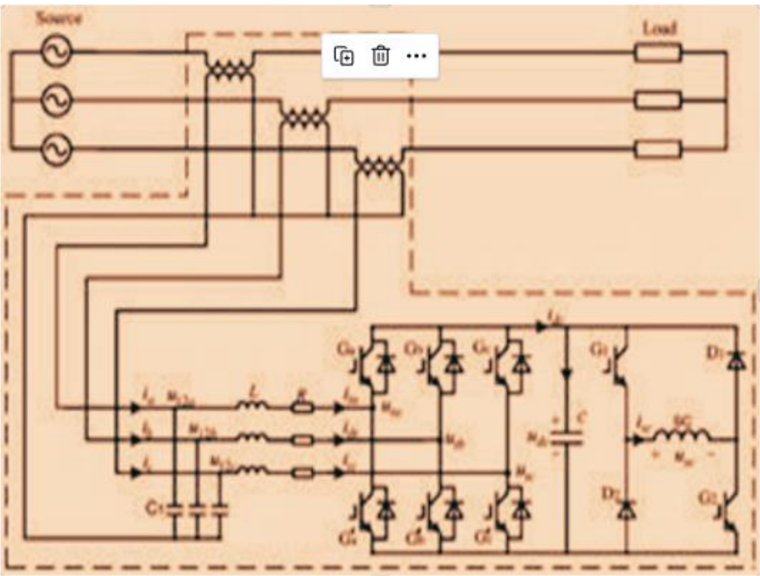

Figure 1: DVR's fundamental design is based on SMES. Its circuit that discharged energy

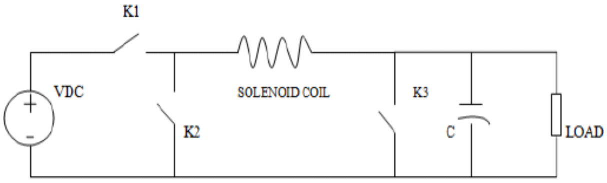

Figure 2: Circuit for SMES energy release The circuit model has three operational states.

Energy is conserved as the solenoid coil constantly transfers current via the coils without degrading. Negative voltage is delivered across the solenoid coil to release the energy that has been trapped there. As seen in Figure 3, a practical application employs a discrete pulse width modulation-based control method with reference to DVR to reduce the simulated voltage. A distinct phase failure at the load terminals is what causes voltage sag, swell, and interruption, as depicted in Fig. 4. Under these conditions, the control strategy seeks to keep the voltage magnitude constant at the sensitive load point. A base voltage of one voltage per module at the load terminals is maintained by the IGBT under control of the PI controller.

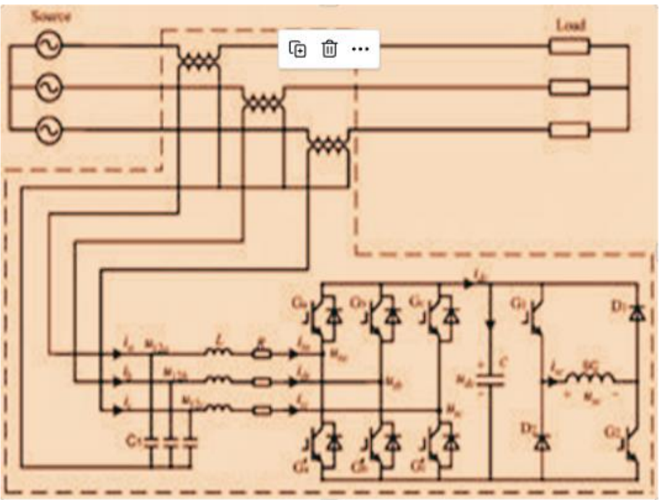

Figure 3: DVRS and SMES (SMES based)

$$v_A = \text{Sin}(\omega t + \delta)$$
$$v_B = \text{Sin}(\omega t + \delta - 2\pi/3)$$
$$v_C = \text{Sin}(\omega t + \delta + 2\pi/3)$$

An actuation signal or the difference between V reference and V input is used as the input to the PI controller. The output of the controller block is an angle with V ref equal to one p.u. voltage in the three phase voltages. The load terminals have voltage in p.u. [8]. The necessary firing sequence is produced when the controller output is contrasted at the signal generator for pulse width modulation.

4. MODEL FOR SMES SIMULATION

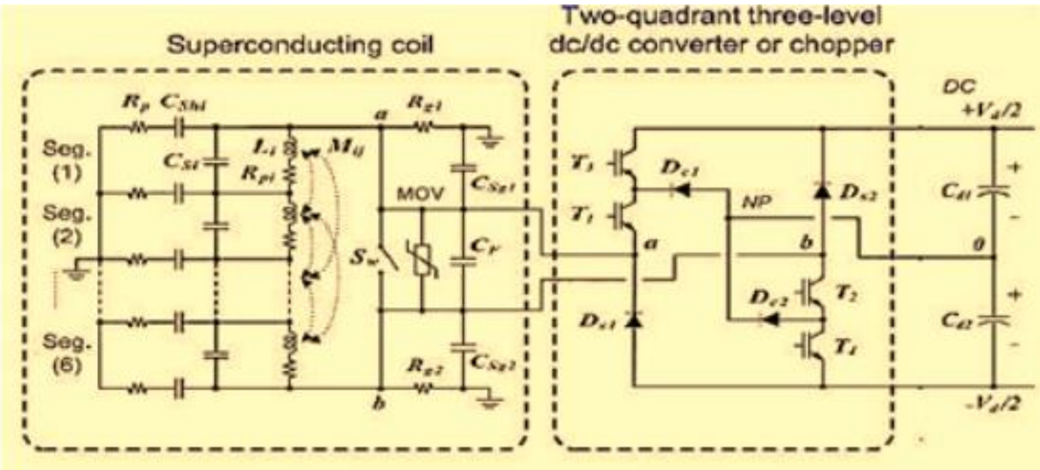

Fig. 4: A thorough illustration of the suggested SMES system

The pertinent igbt switching states for three-level chopper output voltage vectors are displayed in Table 5. The associated SMES charging and discharging outputs are given in Figs. 9 and 10, and the Matlab model is depicted in Fig. 4. Figure 6 shows the Waveform of the SMES model's output and discharge

Table 5: output voltage vectors for a three-level chopper and the related IGBT switching states

States	T_1	T_2	T_3	T_4	V_{ab}
1	1	1	1	1	$+V_d$
2	0	0	0	0	$-V_d$
3	0	1	0	1	0
4	1	0	1	0	0
5	1	1	0	0	0
6	1	1	0	1	$+V_d/2$
7	1	1	1	0	$+V_d/2$
8	1	0	0	0	$-V_d/2$
9	0	1	0	0	$-V_d/2$

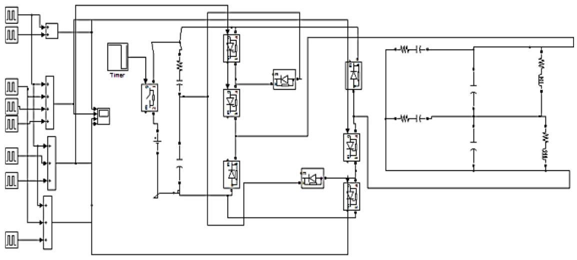

Fig. 5: SMES model in MATLAB/SIMULINK diagram.

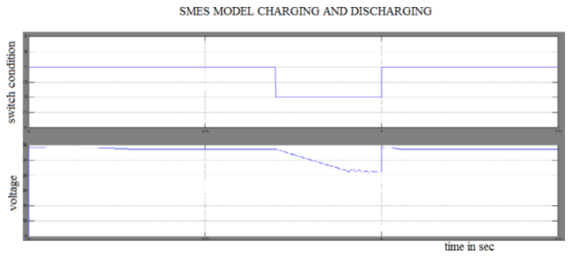

Figure 6: Waveform of the SMES model's output and discharge

5. SMES BASED ON DVR TESTSYSTEM

The single line schematic of the 13 kV test system depicts the SMES, 50 Hz generation system, which powers 2 powerlines via a 3-winding transformer, as a single line. It evaluates the DVR's capability to correct for voltage for a fixed time of 200 ms at a fault resistance of 0.44 ohms. SMES has a 588 KA current flowing through it, and this is taken into account while analysing the performance of the system [11].he single SMES coil is connected to many power lines in this novel idea using an upgraded current-voltage (I/V) chopper assembly, which has a number of input/output power ports [10]. Fig. 5 shows a SIMULINK or MATLAB diagram of a SMES-based DVR. Fig 7 to 13 shows the SMES-based DVR at different ways.

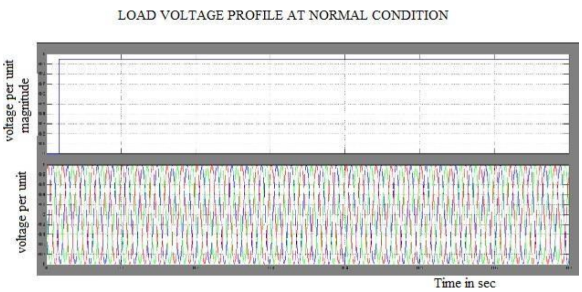

Figure 7: Voltage in phase with no faults

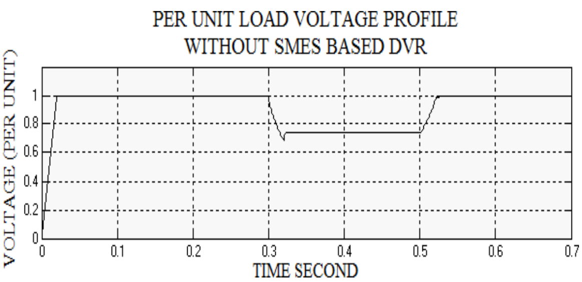

Figure 8: Phase-phase voltage with a single line fault but no SMES-based DVR

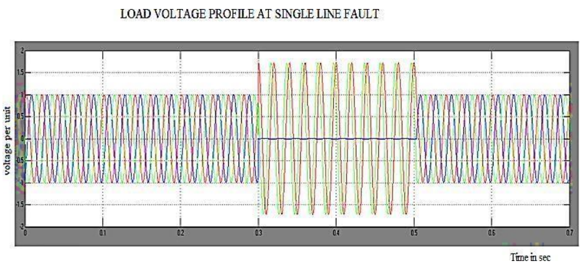

Figure 9: Without a SMES-based DVR and a line-line failure, phase-phase voltage

Figure 10: phase-phase voltage during a three-phase failure without a SMES-based DVR

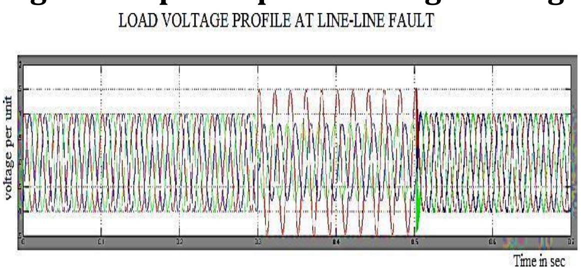

Figure 11: Voltage P.U. at the load point without a SMES-based DVR

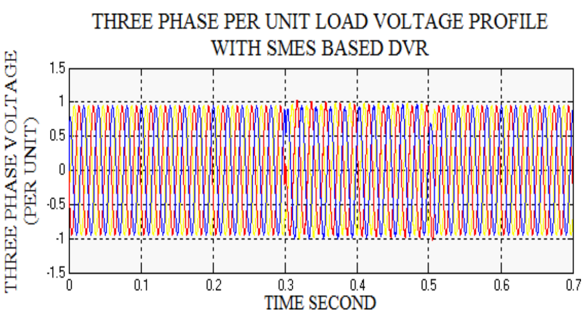

Figure 12: 3-phase P.U. voltage at the load point and SMES-based DVR

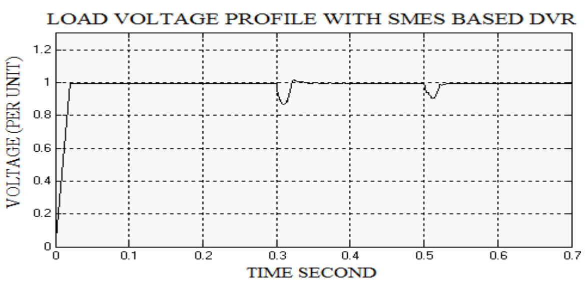

Figure 13: Voltage P.U. with a SMES-based DVR at the load point

6. CONCLUSION

By controlling and enhancing the intended voltage load size and THD within points of conflict, the suggested technique is employed for voltage list ID and is suitable for list placement. Although it has only been used for one trade at each stage, the suggested technique is fairly reliable and simple. As a result, despite the structure's simplicity and lack of complexity, an energy storage system is needed.

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