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Zero Voltage Switching Technique for Bidirectional DC-DC Converter

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***Abstract* - A high power bidirectional dc-dc converter with discontinuous conducting mode (DCM) and low inductance may reach greater power densities while using less power. DCM-related current ripple is minimised to a bare minimum with multiphase interleaved operation. It is required to discharge the energy stored in the capacitor before the device may be turned on. When the active switch is switched on, a complementary gating signal control approach is utilised to turn on the non-active switch, which aids in draining the capacitor and channelling the current through the active switch's anti-parallel diode. This technology achieves zero voltage resonant transition (ZVRT) in principal switches. In addition, utilising this method eliminates parasitic ringing in the inductor current. The approaches suggested in this study are based on snubber capacitors and optimising inductance. For the functioning of a bidirectional DC-DC converter, zero voltage switching is accomplished in this paper.**

***Index Terms* - DC-DC converter, DCM's, ZVRT, snubber capacitors**

I.INTRODUCTION

Bidirectional dc-dc converters have surfaced as a viable solution for a range of power-related systems, including hybrid automobiles [1, fuel cell vehicles, renewable energy systems, and other similar systems. The outcome is that not only do costs and efficiency improve, but the general performance of the system is improved as well.

When an electric machine generates energy, it is stored in an auxiliary energy storage battery, which is utilised to power the vehicle in the case of electric vehicles. As indicated in the bidirectional dc-dc converter represented in the figure, it is also important to draw power from the auxiliary battery in order to improve performance of the high-voltage bus during vehicle starting, acceleration, and hill climbing. In order to transmit power between two dc power sources in either direction, bidirectional dc-dc converters are becoming more common. These converters have the capability of reversing the direction of current flow and hence power transmission.

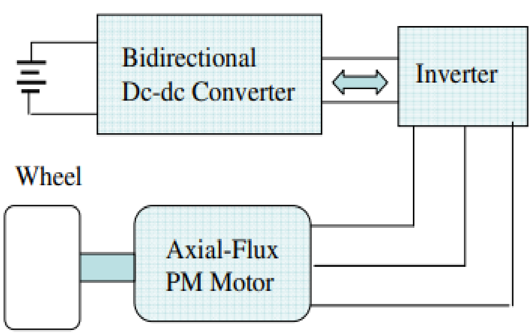

Figure 1. Bidirectional DC-DC Converter.

A. *Non Isolated Bidirectional converters:*

An example of a non-isolated bidirectional DC-to-DC converter design is seen in Figure. It consists of a step-up stage that is connected in anti parallel with a step-down stage that is connected in parallel with one another. During motor driving operations, the converter jump stage is used to raise the battery voltage and regulate the inverter input, both of which are performed by the converter. Utilizing the step-down stage of the converter, it is feasible to create vehicle regenerative braking by providing a channel for the braking current and allowing for the recovery of vehicle energy stored in the battery.

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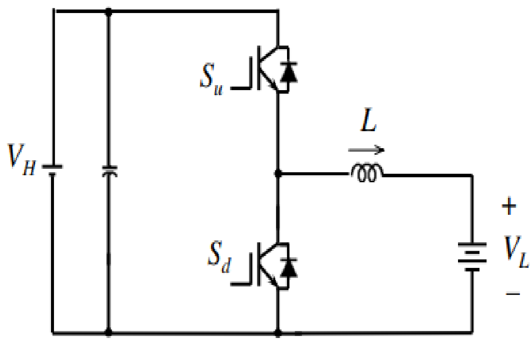


Figure 2. *With Buck Boost structure.*

B. Bidirectional Isolated DC-DC Converters:

Bidirectional dc-dc converters often use transformers to provide electrical isolation between the two sides of the converter. It is certain that the installation of a transformer would result in higher expenses and losses. However, since a transformer is capable of separating the two voltage sources while still supplying the appropriate characteristic impedance between them, it is a feasible option in these sorts of circumstances. In order for a current source to work properly, inductance is often necessary in the centre. Depending on the arrangement, the sub-topology for isolated bidirectional direct current to direct current converters may be a full-bridge, a half-bridge, a push-pull circuit, or a mix of these configurations.

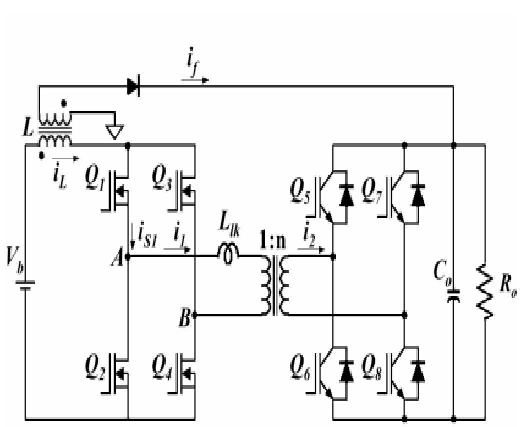


Figure 3. *Isolated converter.*

One type of isolated bidirectional dc-dc converter is constructed using a high frequency isolation transformer as both the primary and secondary of the converter. A half-bridge is used on the primary side of the converter, and a push-pull current is supplied from the primary to the secondary of the converter.

The converter's operation is described in full in both modes: while the dc bus is available, the battery is charged, and when the dc bus is gone, the battery supplies power. In particular, this converter is well suited for battery charging and discharging circuits in uninterruptible power sources that run at a constant direct current (dc) voltage (UPS). Among the advantages of this proposed converter topology are electrical isolation between the two dc sources, which is achieved by using only a single transformer, a low part count, which is achieved by using the same power components for power flow in either direction, and a low part count, which is achieved through the use of the same power components for power flow in either direction.

II DESIGN ASPECTS OF CONVERTER

In non-isolated bidirectional direct current to direct current converter technology, half-bridge topologies of buck and boost converters are utilised in conjunction with each other. It is feasible to design the converter to operate in discontinuous conducting mode (DCM) in order to achieve high power density while at the same time minimising the size of the passive inductor used in the converter. It is necessary to interleave numerous phases in order to neutralise the high-frequency switching current ripple generated by the DCM operation since it creates a substantial quantity of current ripple during the process. It has been stated that work has been done on the creation of a 36-phase interleaved converter.

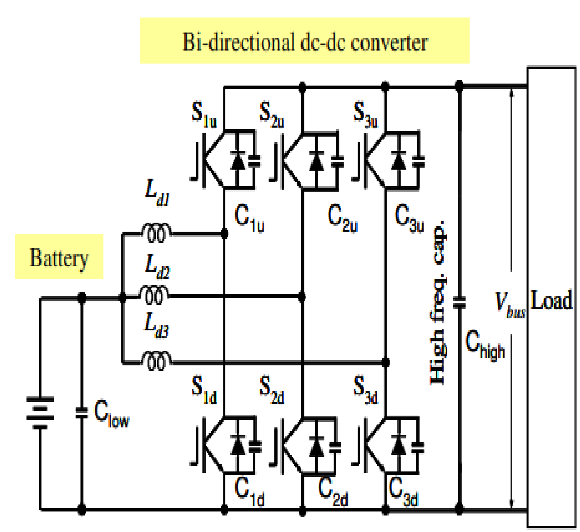


Figure 4. *ZVS concept in interleaved converter.*

Using a connected inductor approach, it is also possible to reduce the amount of ripple present in the signal. One additional key advantage of DCM operation is the lack of turn-on loss, which, as a consequence, allows the use of a low-power diode to completely reverse recovery loss. The functioning of the DCM, on the other hand, results in a large increase in turn-off loss since the main switch is shut down at double the load current or more when the DCM is operational.

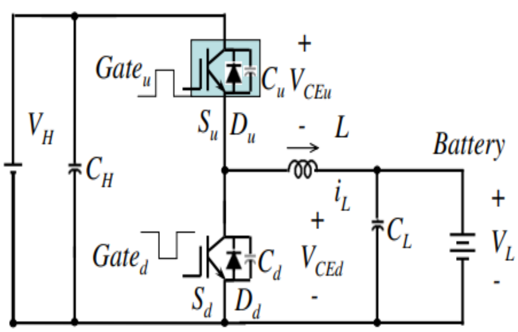


Figure 5. *Circuit diagram.*

The most major negative side effect of lowering the inductor size is the increase in the frequency of the inductor. Because the inductor's current fluctuates with the device's output capacitance throughout the device's turn-off period, inductor current parasitic ringing is also produced (also known as inductor ringing). All of these undesirable effects that may be generated by the DCM may have a detrimental influence on the device's overall effectiveness.

A. Inductor Design:

Following are the expressions used for inductor optimization.

$$\Delta I = \frac{1}{2} \cdot \frac{V_{in} - V_o}{L} \cdot \frac{V_o}{V_{in}} \cdot T_s$$

$$I_{Load} = \frac{P}{V_o}$$

$$I_{peak} = I_{Load} + \Delta I$$

$$I_{\min} = I_{Load} - \Delta I$$

$$I_{rms} = \sqrt{I_{Load}^{2} + \frac{\Delta I^2}{3}}$$

Following are the realization of soft switching

$$L_{cr} = \frac{1}{2} \cdot \frac{V_{in} - V_o}{P} \cdot \frac{V_o^{2}}{V_{in}} \cdot T_s$$

III POWER CIRCUIT MODELLING

There is an introduction to a coupled-inductor system, which has the goal of improving the design of power stages in order to reduce core loss. In order to improve the overall performance of the system, it is necessary to model the coupled inductor and provide a simplified model for the system controller to be used in the design. Using coupled inductors, it is feasible to conduct a comprehensive analysis of the power stage. It is necessary to test the simplified coupled inductor model, which is offered as an example, with the help of the Simples ac analysis simulation.

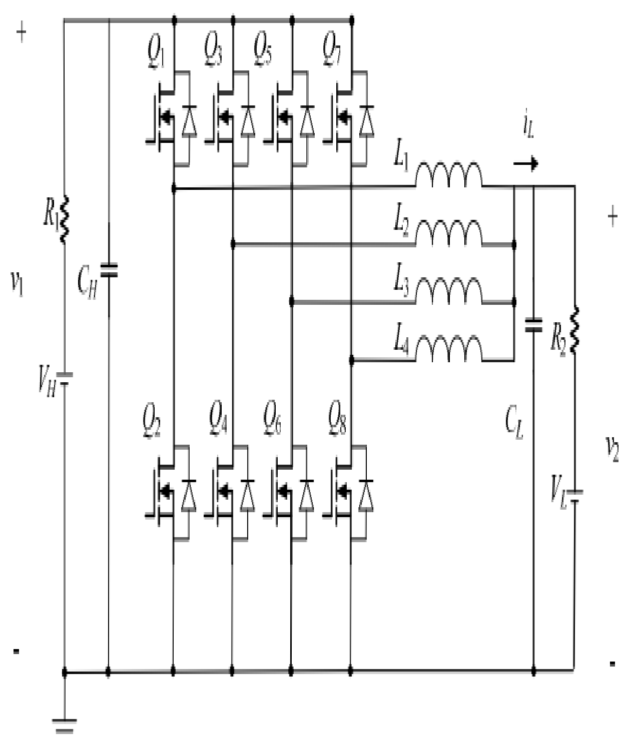


Figure 6. *General purpose bidirectional converter.*

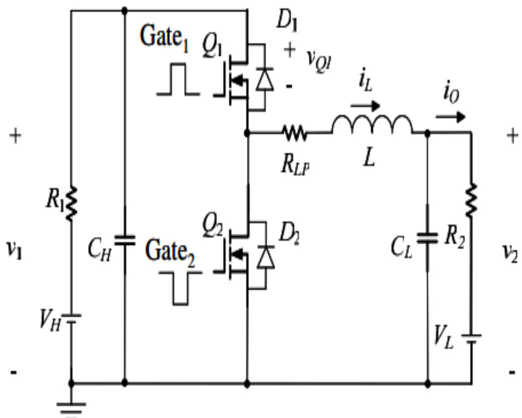


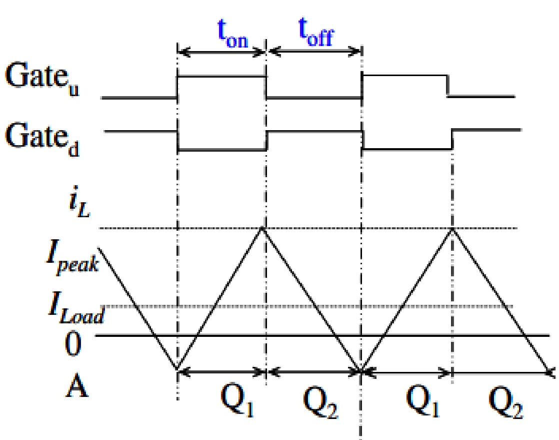
Figure 7. *Single phase DC-DC converter.*

Following are the assumptions:

- Very small ripple content is presented.
- It is assumed that current is small

A. State Space Model:

The discussion in Chapter 2 and the assumptions mentioned above lead to the observation that no matter whether operating modes are utilised, whether in battery charging mode or in battery discharging mode, there are always two subintervals tonne and toff, as shown in Figure 1. During the first subinterval, when the switch Q1 is switched on and the switch Q2 is turned off, the converter equivalent circuit may be seen in the figure below, which represents the converter equivalent circuit.



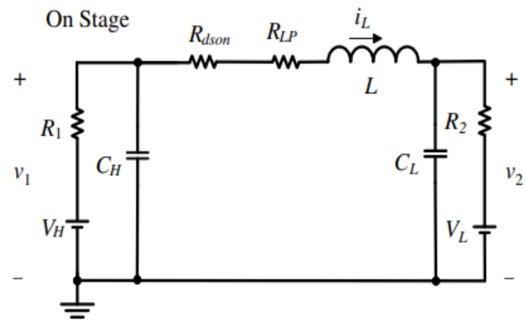


Figure 8. *Gate signal and its model.*

Following expressions represents its model.

$$L\frac{di_L}{dt} + i_L \cdot (R_{dson} + R_{LP}) = v_1 - v_2$$

$$\begin{cases} C_H \dfrac{dv_1}{dt} = -(i_L + \dfrac{v_1 - V_H}{R_1}) \\ C_L \dfrac{dv_2}{dt} = i_L - \dfrac{v_2 - V_L}{R_1} \end{cases}$$

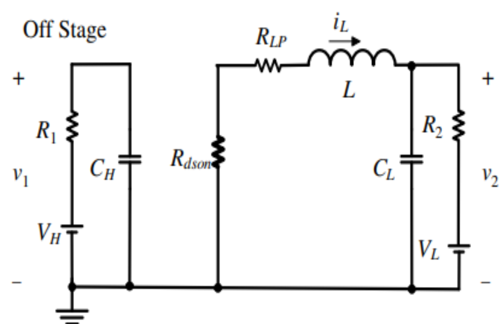


Figure 9. *Snubber circuit.*

$$L\frac{di_L}{dt} + i_L \cdot (R_{dson} + R_{LP}) = -v_2$$

$$\begin{cases} C_H \dfrac{dv_1}{dt} = -\dfrac{v_1 - V_H}{R_1} \\ C_L \dfrac{dv_2}{dt} = i_L - \dfrac{v_2 - V_L}{R_1} \end{cases}$$

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IV CONTROLLER DESIGN

It is difficult to synchronise several phases of PWM signals and achieve a precise PWM duty cycle in an analogue implementation due to the various performance of the discrete components due to their distinct performance. When producing multiphase interleaved gate signals, it is better to use a digital controller rather than a mechanical controller. When used in high-power applications where noise immunity is needed, it provides excellent noise immunity and is hence essential. Furthermore, since the error amplifier of the preferred mode may get saturated during the transition, the analogue implementation is more prone to difficulties during the transition than the digital one, which is a disadvantage.

A. System Design:

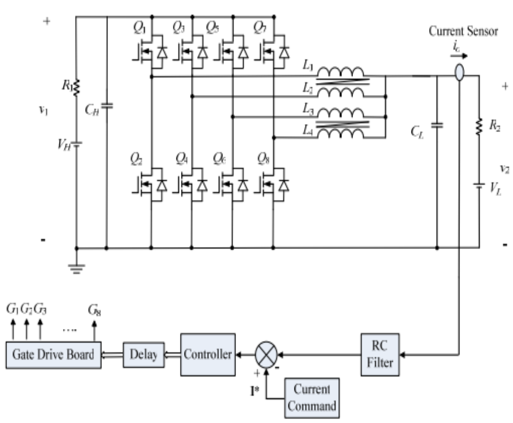


Figure 10. *System Architecture.*

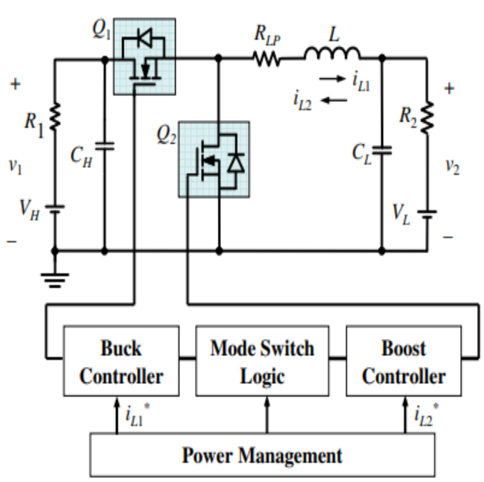


Figure 11. *Individual controllers.*

B. Filter Design:

The total current IL of the inductor is characterised by large peaks and valleys. A four-phase interleaving waveform contains a switching frequency component that is four times as fast as the inductor current ripple frequency of the waveform. However, since there is an imbalance between the four phases, the switching frequency component remains in the waveform. It is thus necessary to use a filter with a low cut-off frequency in order to effectively eliminate the ripple effect. Because the cut-off frequency should be lower than the switching frequency, it is advised that the cut-off frequency be lower than the switching frequency.

$$RC(s) = \frac{1}{(1 + \frac{s}{2 \cdot \pi \cdot f_c})^2}$$

$$BF(s) = \frac{1}{1 + 1.414 \cdot \frac{s}{2 \cdot \pi \cdot f_c} + \left(\frac{s}{2 \cdot \pi \cdot f_c} \right)^2}$$

V SIMULATION RESULTS

This is an example of a closed loop. It was necessary to simulate the Bidirectional Converter feeding the PMDC Motor with the appropriate values, which was done in Matlab Simulink using the planned values. They were deemed satisfactory and in accordance with expectations based on the results of the simulation. The following are some of the many waveforms that are available:

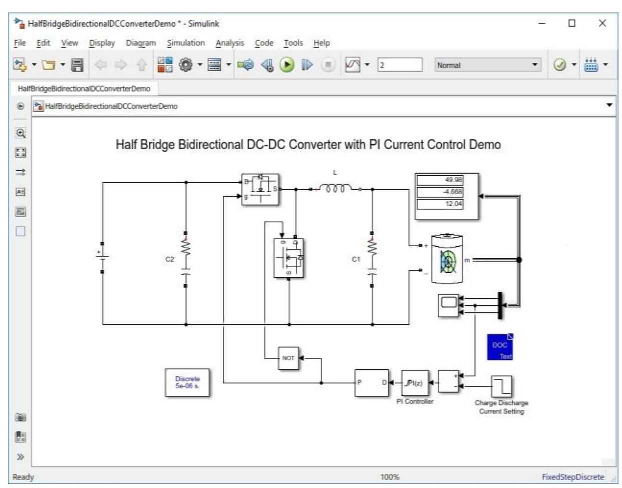


Figure 12. *Model in SIMULINK.*

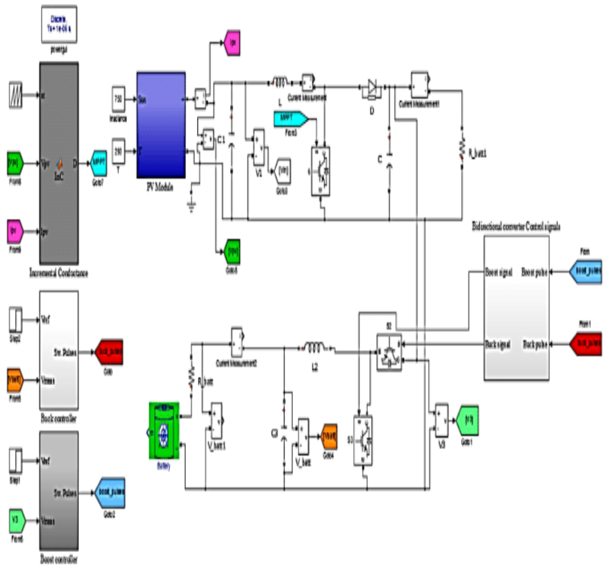
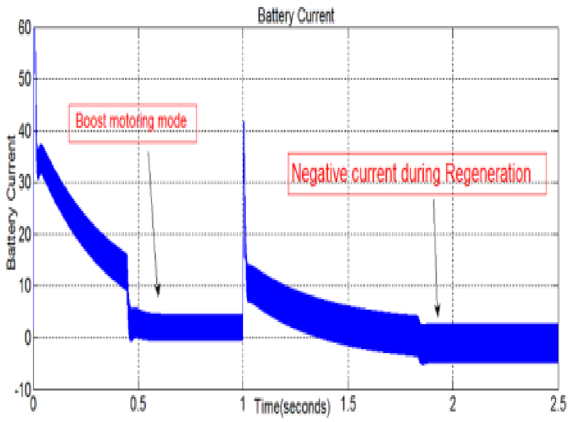


Figure 13. *Internal Block.*



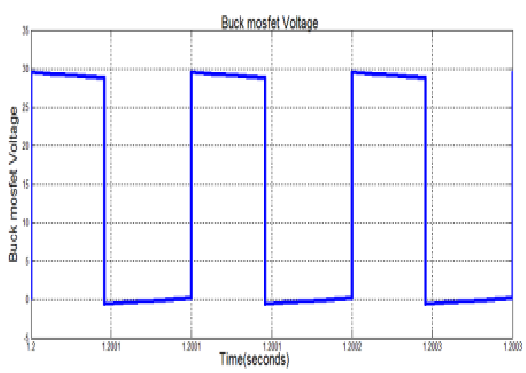


Figure 14. *Buck voltage.*

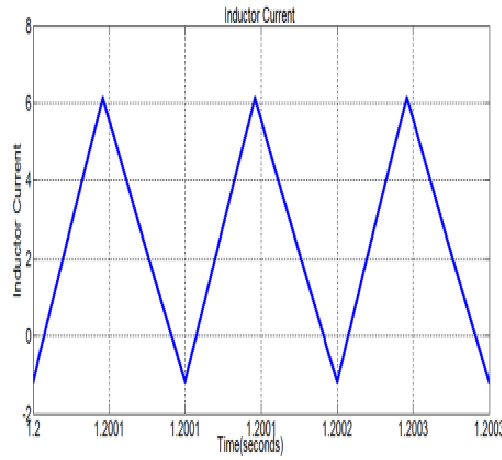


Figure 15. *Inductor current.*

CONCLUSION

- Following are the conclusions of the work carried out
- A bidirectional DC-DC converter is designed.
- ZVS switching scheme is implemented
- Ripple content is reduced negligibly.

FUTURE SCOPE

Following aspects are left as future scope of this project.

- Design needs to be verified with discontinuous load.
- Advanced control scheme needs to be implemented.

REFERENCES

1. A. Oudalov, T. Buehler and D. Chartouni, "Utility Scale Applications of Energy Storage," 2008 IEEE Energy 2030 Conference, Atlanta, GA, pp. 1-7, 2008.
2. H. Qian, J. Zhang, J. S. Lai and W. Yu, "A high-efficiency grid-tie battery energy storage system," in IEEE Transactions on Power Electronics, vol. 26, no. 3, pp. 886-896, March 2011.
3. M. Guarnieri, P. Mattavelli, G. Petrone and G. Spagnuolo, "Vanadium Redox Flow Batteries: Potentials and Challenges of an Emerging Storage Technology," in IEEE Industrial Electronics Magazine, vol. 10, no. 4, pp. 20-31, Dec. 2016.
4. R. Sathishkumar, S. K. Kollimalla and M. K. Mishra, "Dynamic energy management of microgrids using battery super capacitor

combined storage," 2012 Annual IEEE India Conference (INDICON), Kochi, pp. 1078-1083, 2012.

5. J. S. Lai and M. W. Ellis, "Fuel Cell Power Systems and Applications," in Proceedings of the IEEE, vol. 105, no. 11, pp. 2166-2190, Nov. 2017.
6. K. Zhang, C. Mao, J. Lu, D. Wang, X. Chen and J. Zhang, "Optimal control of state-of-charge of superconducting magnetic energy storage for wind power system," in IET Renewable Power

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