Journal of Futuristic Sciences and Applications
Vol. 5(1), Jan-Jun 2022, pp. 77-85
doi: 10.51976/jfsa.512211
www.gla.ac.in/journals/jfsa

C-Dump Converter Employed with Switched Reluctance Motor

Toran Verma and Shivani Agarwal***

ABSTRACT

Switched reluctance motors are among the finest competitors to induction motors. It is a well-liked choice because of its durability, brevity, straightforward design, and superior torque to mass ratio. This page talks about the C-dump converter's design. The C-Dump converter makes it possible for the phase winding to be rapidly demagnetized and magnetized, which prevents the motor from being used in the generating state. Currents in the stator winding of a switching reluctance motor have a direct impact on the torque generated. A large negative voltage must be offered in order to quickly stop the current while it is working in the demagnetizing phase. This paper analyzes the C-dump converter's design. The C-Dump converter makes it possible for the phase winding to be rapidly demagnetized and magnetized, which prevents the motor from being used in the generating state. Switched reluctance motors demonstrate a variety of converter topologies for adjusting speed, power, and operation. Additionally, it frequently makes use of the energy that has accumulated in the phase winding and can be returned to the source. Some modified C-Dump converter topologies can utilize this stored energy to bypass the motor's next phase winding.

Keywords: *Semiconductor Devices; Sensor; Controller; DC Source; Switched Reluctance Motor; Torque.*

1.0 Introduction

The switching reluctance motor was made possible by the synchronous reluctance engine of the 19th century. It is fundamentally sound, appropriate, adaptable to different industrial environments, and produces more energy than an induction generator. Because of technological advancements in power semiconductor converters, new switches like MOSFETs and IGBTs can now function at higher system frequencies and at higher power levels. Motors can now operate at higher speeds more easily [1]. Basic control circuits could be constructed in order to control the power electronic devices. Bridge topologies were created for managing phase winding excitation; they were simple to run and produce. 2N switches are needed, where N represents the phases of the motor, to reduce the quantity of diodes and system losses. Phase winding of Switched Reluctance motor The motor was started via switching devices. Mechanical switches require manual operation and take much longer to turn on and off, making it more challenging to regulate the motor's speed and limiting its higher operating speed. Switching reluctance magnets were not employed in industry for servo and non-servo uses because it was difficult to control the speed of movement via manual switching after

**Corresponding author; CMR Engineering College, Hyderabad, Telangana, India (E-mail: toranverma.003@gmail.com)*
***Assistant Professor, Dr. A. P. J Abdul Kalam Technical University, Lucknow, Uttar Pradesh, India (E-mail: agarwalshivani@akgec.ac.)*

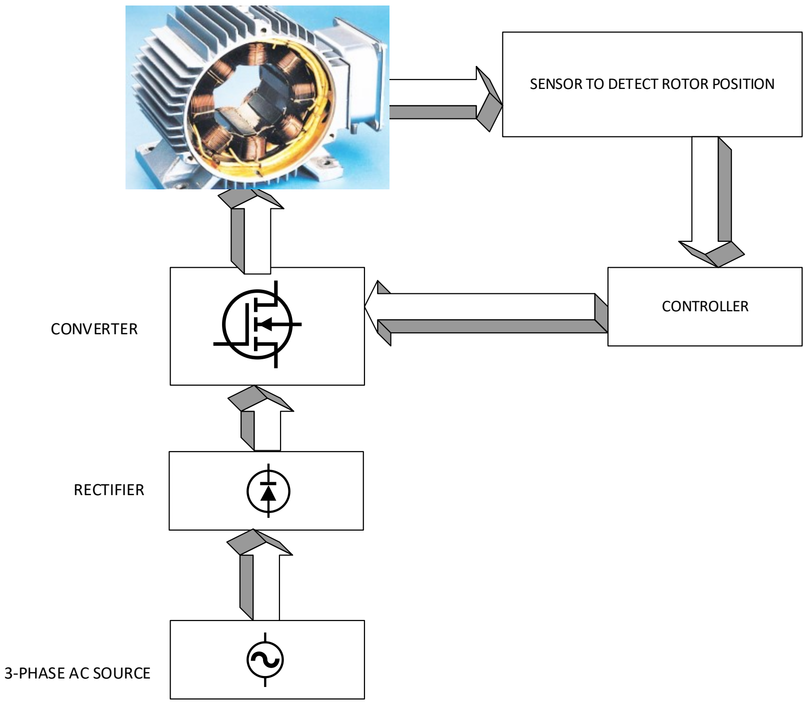
Doi: 10.51976/jfsa.512211

their introduction [1]. The SRM is driven by a single-directional current pulse [2]. The phase winding was initially stopped using manual switches [1, 17]. Numerous novel converters have emerged as a result of advancements in semiconductors. This architecture featured a greater proportion of semiconductor components, which increased the system's cost and losses. Despite being simple to run and build, full and half bridge converter topologies have larger losses since there are so many components. These converters continue to be unable to transfer energy into phase winding, which is in charge of energy loss from passive components. The advantage of the traditional C-Dump is that it provides the energy saved during the commute. Either it is transmitted back to the source directly or it is used to power the next winding process. Only a small number of unique modified topologies have been developed that reduce system losses by lessening the converter's element ratings and operability. Due to its properties, the C- Dump converter is perfect to be used in hybrid cars.

2.0 Operation of Motor (Switch Reluctance Motor)

It was important to modify the power and torque of a switching reluctance motor at various intervals. This control has led to a sharp increase in the use of switched reluctance motors in commercial and residential applications in Swit's characteristics. As a result of technological advancements in power devices, the switching reluctance motor has been revived. In nature, both the stator and the rotor are significant As a result of technological advancements in power devices, the switching reluctance motor has been revived. The application, operating speed, and power output are taken into consideration when choosing the stator and rotor poles.

Figure 1: Switched Reluctance Motor Working



As the number of stator and rotor poles climbs, so does the number of stages in the stator and, as a result, the quantity of converters. As when the number of phases rises, so does the complexity of the circuitry. Operating a rotor at a higher speed is particularly difficult, though, because there are fewer stator poles [1, 17]. The lack of winding on the rotor poles of the motors lowers the design's mass and inertia. Rotor is ideal for high-speed applications like compressors, aircraft, and e-mobility since it is lighter, has less inertia, and can spin more quickly. Due to the saliency feature, the air gap in motors is typically not smooth and offers more resistance to the flux produced by the stator. [2, 16]. Since stator pole windings are arranged in series to create a single phase, the quantity of stator pole pairs is exactly proportional to the number of phases in the motor. A motor's ability to operate at greater speeds is subject to many limitations due to correct energy transfer. [3]. A unique type of hesitation is referred to as "flipped reluctance." High torque ripple in the engine's outputs creates missing in the rotor and the stator pole, which results in vibration and audible noise. [5, 7]. The phase inductance is greatest at the joint contact of the stator and rotor pole tip, represented by La, since the maximal stator flux is connected with the rotor structure.

Fig 1 shows a Switched Reluctance Motor's operational circuit design. It includes a source, a rectifier, a converter, a microcontroller, a motion detector, and a motor, among other components. Phase inductance is calculated using the rotational speed and current. Depending on the position of the current via the phase circuit, magnetic southern and northern poles form on the pole tip when a stator pole is triggered. The poles with the opposite polarity are created by the opposite pole tip.

2.1 Sensor to detect rotor position

A position sensor is used to determine the location of the rotor pole. To keep the motor spinning, it's essential to recognize the rotor position and move on to the following stator phase. Infrared and Hall sensors are often utilized as location detectors. The position sensor increases the system's cost, reduces the system's robustness, and increases the complexity of the control circuit. Switched Reluctance is a general term for several types of resistance. The position of the rotor greatly influences the motors. If the rotational speed data is inaccurate, torque prediction and management errors will occur.

2.2 DC source

An alternative to the rectifier circuit is a DC supply. The type of converters and the maximum capacity of the motor decide the supply voltage that is provided. A larger power source lowers the circuit's lowest limit and hence minimizes losses while simultaneously increasing the device's voltage level. Voltage drop, however, results in increased energy losses because it takes more voltage to produce the desired results.

2.3 Converter

A unidirectional current pulse must always be applied to the converter's phase winding. Voltages and currents in a converter define its KVA factor. The drive system's overall efficiency is significantly impacted by the converter. The converter's performance and design will determine the motor's simple design, variable speed, and torque ripple reduction at the outputs. The converters should be able to independently control every cycle winding. Independent phase control is the only option in the absence of a linked inductor in the winding, which reduces fault in the converters and makes them fault resistant. To avoid negative torque ripple, the converters must have fewer switches and be able to quickly feed magnetization and demagnetization voltage to the main voltage. A unidirectional current pulse is sent to the stator phase coil by the converters, which are made up of power switches and semiconductor circuits. The topology has an impact on the size, shape, and number of switches. [16]. The drive mechanism's converter design is suggested in this section. The

Doi: 10.51976/jfsa.512211

complexities and control circuitry of a circuit are determined by the number of phases and switches. In order to reduce costs, raise complexity, cut losses, and enhance drive performance, it is crucial to choose an appropriate converter design.

2.4 Controller

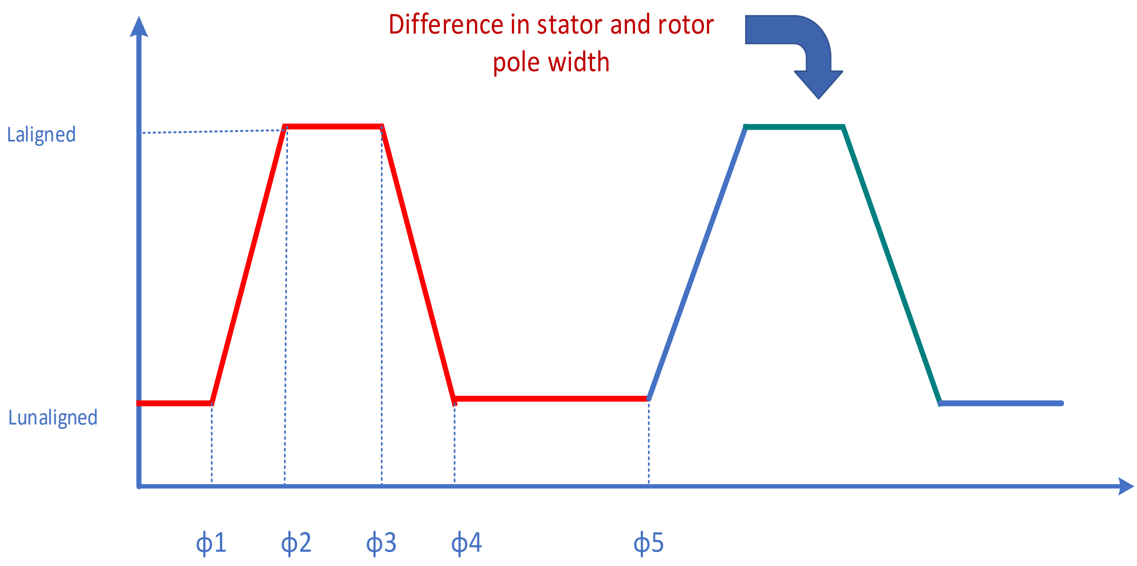
In accordance with the rotor, the controller controls phase winding flipping and maintains phase magnetization and demagnetization. Depending on the application, controllers assist in controlling switches, maintaining rotational direction, and regulating motor running speed. A controller with real-time waveforms of optimal current is necessary for SRM motors [7, 11].

2.5 Production of torque

The placement of the rotor and stator poles, as well as the architecture of the pole, all have an impact on the resulting torque, which is discontinuous [5, 7 & 11]. The relationship shown below is used to calculate the torque generated.

$$T_i = \frac{i^2}{2} \cdot \frac{dL(i,\theta)}{dt} = \frac{(current\ in\ phase\ winding)^2}{2} \cdot \ Rate\ of\ change\ of\ phase\ inductance \quad \ldots(1)$$

Figure 2: SRM Inductance Profile

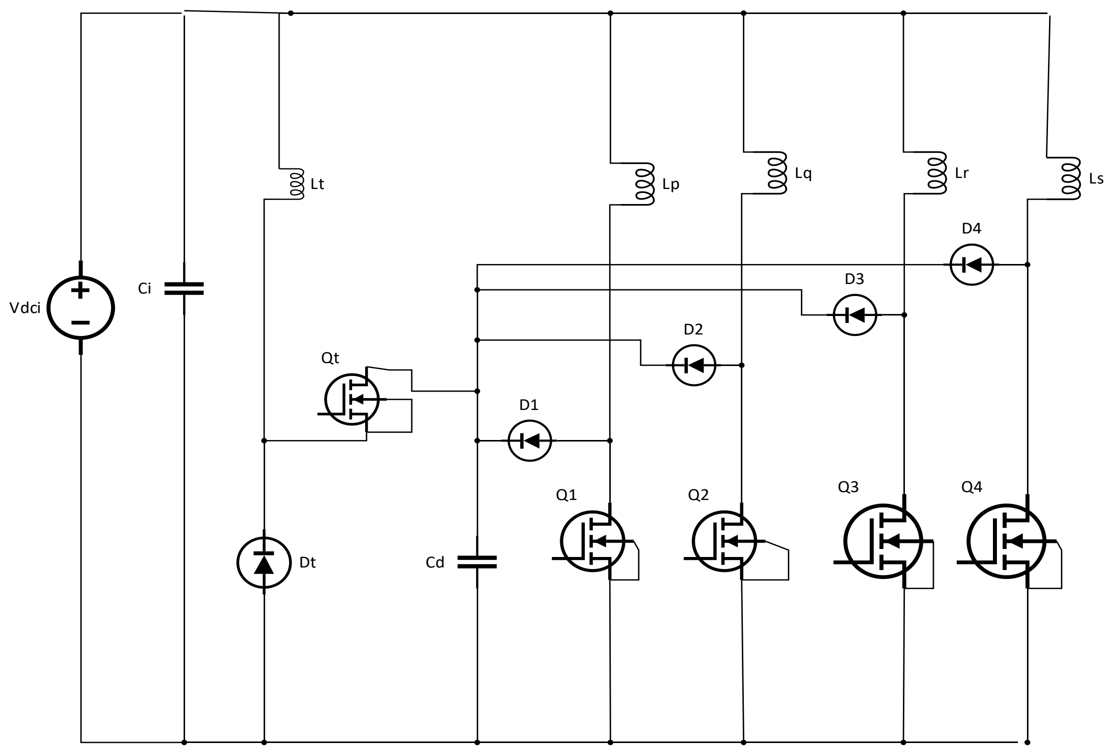


The creation of flux in the air pocket occurs after the phase winding is excited. The magnetic poles formed on the tips of the rotor's magnetic poles produce the force of attraction between the stator and rotor poles. This attraction force causes the rotor to align itself with the stator. The SRM's inductance profile is shown in Figure 2. The positive slope of the inductance profiles indicates that when the rotor moves from an unaligned to an aligned position, the flux linkages with the rotor structure expand, leading to an increase in phase inductance. At second instant, the stator and rotor are matched, and the flat area of the inductance curves indicates that the width difference between the rotor and stator sides causes inductance to remain constant for a while. This flat area prevents the inductance curves from converging and demagnetizes the phase coil. This situation results in constant inductance since the air pocket is unchanged. Despite the fact that inductance isn't truly altered by variations in rotor position, electricity begins to flow through the phase coil. By allowing the stator current to drop to a lower or zero level and limiting the development of negative torque, this section facilitates the commutation of phases. At third instant, the power is disconnected from the phase as the phase coil starts to demagnetize. The energy held in the phase winding is released or delivered straight to the origin depending on the converter topology. The C-Dump converters send this power to the supply after storing it in the dump capacitors. This stored energy is used by several contemporary converter topologies to connect the subsequent phase coil. The motor can be turned on in the generating mode when the value is negative, which denotes phase coil demagnetization [3]. The motor has produced a negative torque, and this will result in torque waves. When the rotor moves away from the stator, which is referred to as being in an unaligned position, the phase inductance is reduced to its lowest level. The torque is equal to the phase current squared and is unaffected by the direction of current flow, much like a DC series motor. A unidirectional current pulse is applied to the phase winding, allowing the motor to operate in four quadrants [2]. In order to reduce the airgap between the rotor and stator, the radial magnetic field will cause vibrations that push the poles of the two components closer together.

3.0 Operation of C-Dump Converter

One straightforward illustration of a Buck converter is the C-dump converter [6, 15]. At phase commutation, electricity is generated in a dumping capacitor. This energy could be wasted on inactive components instead. For rapid demagnetization, this energy can either be sent back to the source or applied as a low polarity across the switching main voltage [1 to 12]. The basic C- Dump design can be used to create a few alternative, more flexible circuits depending on how the energy is used. The converters' architecture is described further below: Energy-efficient CDC, conventional CDC, and modified CDC are the available options.

Figure 3: C-Dump Converter



Doi: 10.51976/jfsa.512211

The ability of C-dump capacitors to recover the energy accumulated during the demagnetization process has fueled the development of this type of converter. The phase coil begins to magnetise when phase runs out of supply. When Imax and Vdci are reached, the phase coil's arrangement is reversed, which leads to the forward biassing of diode D1. The phase winding's cumulative energy will be received by the dump capacitor, which will then store it while maintaining the Vdci+v voltage across it. Switch Q1 lowers the voltage across the dump capacitor, allowing the energy to be transferred from the capacitor to the source. Figure 3 illustrates the C-dump converter's chopper circuit (Lt, Qt, and Dt) and dump capacitor. [3, 12 & 16]. Operating the C-Dump converter is very challenging due to the presence of a chopper circuit.

4.0 Simulation Results

The simulation employs open loop control, and triggering pulses are produced using a pulse generator. It is discovered that the switching frequency is 834Hz. By charging or discharging the dump capacitor, the Switch Qt supplies power to the device. To trigger switch Qt, the phase sequence and capacitor voltage pulses must be in the right order, and the voltage across the dumping capacitors is measured in order to generate that pulse. The equations 2 to 7 are used to calculate the motor parameters for the simulation model, as seen in the table above. Figure 7 displays the C-Dump system's phase voltage result (a). Due to energy stored in the phase winding, the capacitor was charged up to Vdc + v, and the voltage across the c-dump was 120V. Phase commutation causes a voltage drop across the phase winding, which speeds up the demagnetization of the phase winding. the actual value of 30.1942 V and the plotted value of v = 40 V. The voltage of the dump capacitor is found to be 183V. Figure 7(b) displays the output for phase flux connections; the positive slope of the curve depicts rotor movement toward aligned position, whereas inductance rises as the flux connections grow. As phase inductance decreases and the rotor moves away from its joint interface, flux connections weaken, as indicated by the negative slope.

Figure 5 (a): Graph for Phase Voltage vs Time

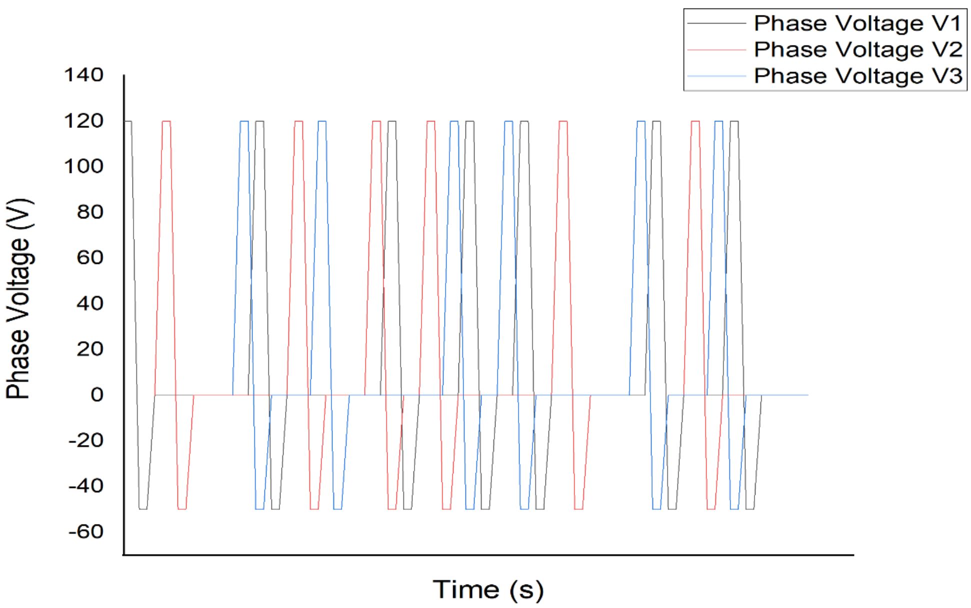
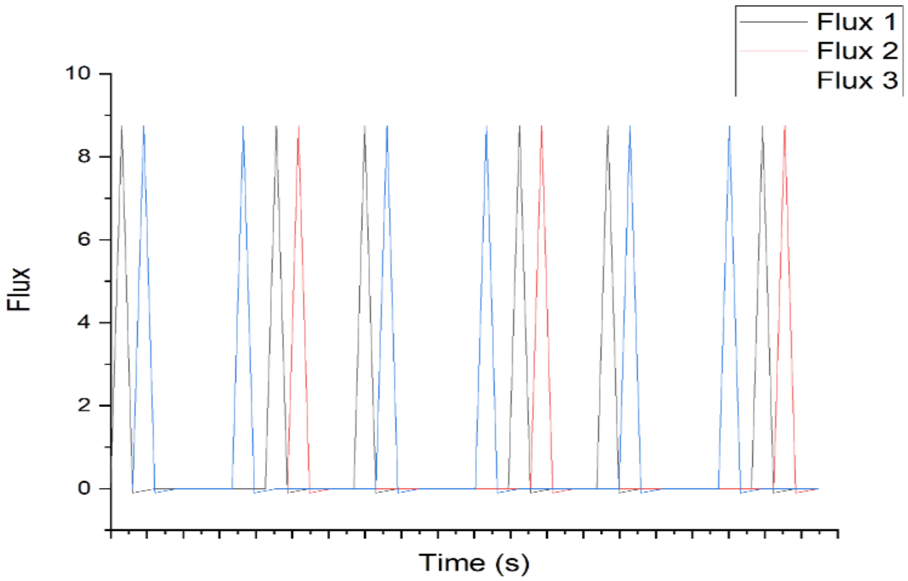


Figure 5(b): Flux Linkages in Each Phase



5.0 Conclusion

The two SRM intervals are realised with the use of Simulink modelling. The voltage "v" applied across the winding during demagnetization is actually the energy held in the dump capacitor. Additionally, Vdci grows in the phase winding during the magnetization interval. We calculated a value of 30.24V, and simulation produced a value of 40V. The obtained capacitor voltage value is 120V in theory, however the actual experimental voltage is found to be 123V. The energy that builds up in the phase winding is what causes the capacitor charge, or Vdci + v. The dump capacitors ought to be capable of withstanding voltages higher than the base voltage.

References

[1] Ahmet M. Hava, Vladimir Blasko, Thomas a. Lipo "A modified C- Dump Converter for Variable-Reluctance Motor", IEEE Transaction on Industry Application, , Vol. 28, no.5, pp.1017- 1022, September/ October 1992.

[2] A. R. Haryawan, "Energy Efficient C-Dump Converter with Inductor for Switched Reluctance Motor," 2018 IEEE Student Conference on Research and Development (SCOReD), 2018, pp. 1-5, doi: 10.1109/SCORED.2018.8710794.

[3] F. Faradjizadeh, M.R. Tavakoli, M. Salehnia, E. Afjei, "C-dump Converter for Switched Reluctance Generator", The Power Electronics, Drives System and Technologies conference (PEDSTC 2014), IEEE, pp. 597-603, Tehran,Iran.

[4] S. Riyadi, "Analysis of C-Dump Converter for SRM Drives," 2018 International Conference on Electrical Engineering and Informatics (ICELTICs), 2018, pp. 179-184, doi: 10.1109/ICELTICS.2018.8548791.

[5] H. Bagherian, M. Asgar, E. Afjei, “A new Converter for Bifilar Winding Switched Reluctance Motor”, 2nd Power Electronics, Drive Systems and Technologies Conference, IEEE Conference 2011, pp. 467-472.

[6] B. Prebin Babu and M. V. Jayan, "A high efficiency novel C-dump topology based converter for SRM," 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), 2017, pp. 1170-1175, doi: 10.1109/ICPCSI.2017.8391894.

[7] Iqbal Hussain, M. Ehsani, “Torque ripple minimization in Switched Reluctance Motor drives by PWM current control”, IEEE Transaction on Power Electronics, Vol. 11, no.1, pp 83-88, January 1996.

[8] K. L. B. Setiawan, "Analysis Performance of Capacitor Voltage in C-Dump Converter for SRM Drive," 2018 IEEE Student Conference on Research and Development (SCOReD), 2018, pp. 1-5, doi: 10.1109/SCORED.2018.8711160.

[9] R. Krishnan, “Switched Reluctance Motor Drives. Modeling, simulation, analysis, design and application” CRC press: 2001.

[10] S. Riyadi and L. H. Pratomo, "Energy Efficient C-Dump Converter with Simple Control Strategy for SRM Drive," 2019 9th International Conference on Power and Energy Systems (ICPES), 2019, pp. 1-5, doi: 10.1109/ICPES47639.2019.9105375.

[11] Jibin Zou, Kai Liu, Jianhui Hu, Junlong Li, “A Modified C-Dump Converter for BLDC Machine used in Flywheel Energy Storage System”, IEEE Transaction on Magnetics, Vol. 47, no. 10, pp. 4175-4178, October 2011.

[12] G. D. Ardine and S. Riyadi, "C-Dump Converter without Inductor for Switched Reluctance Motor Drive," 2018 IEEE Student Conference on Research and Development (SCOReD), 2018, pp. 1-5, doi: 10.1109/SCORED.2018.8711307.

[13] P. Tiwari, P. Sharma, N. Sharma, M. Verma, and Rohitash, “An experimental investigation on metakaoline GGBS based concrete with recycled coarse aggregate,” Materials Today: Proceedings, 2020, doi: https://doi.org/10.1016/j.matpr.2020.07.691.

[14] [6] P. Sharma, N. Sharma, P. Singh, M. Verma, and H. S. Parihar, “Examine the effect of setting time and compressive strength of cement mortar paste using iminodiacetic acid,” Materials Today: Proceedings, vol. 32, no. xxxx, pp. 878–881, 2020, doi: 10.1016/j.matpr.2020.04.336.

[15] King-Jet Tseng, Shuyu Cao, Jijiu wang, “A new Hybrid C-dump and Buck Fronted Converter for Switched Reluctance Motor”, IEEE Transaction on Industrial Electronics, Vol. 47, no.6, pp.1228-1236, December2000.

[16] Krzysztof Tomczewski, Krzysztof Wrobel, “Improved C-dump converter for Switched Reluctance Motor drives”, IET Power Electron 2014, pp.2628-2635.

[17] Omar Ellaban, Haitham Abu-Rub, “Switched Reluctance Motor Converter Topologies: A Review”, International conference on Industrial Technology (ICIT 2014), IEEE, pp. 840-846, Busan, Korea.

[18] Tae-Won Lee, Yong-Ho Yoon, Yuen-Chang Kim, Byoung-Kuk Lee, Chung-Yuen Won, “Control of C-dump converter fed Switched Reluctance Motor on an automotive application” Electric Power System Research 77 (2007), pp. 804-812, Elsevier.

[19] P. Sharma, M. Verma, and N. Sharma, “Examine the Mechanical Properties of Recycled Coarse Aggregate with {MK} {GGBS},” {IOP} Conference Series: Materials Science and Engineering, vol. 1116, no. 1, p. 12152, Apr. 2021, doi: 10.1088/1757-899x/1116/1/012152.

[20] N. Sharma, P. Sharma, and A. K. Parashar, “Incorporation of Silica Fume and Waste Corn Cob Ash in Cement and Concrete for Sustainable Environment,” Materials Today: Proceedings, Apr. 2022, doi: 10.1016/J.MATPR.2022.04.677.

[21] N. Sharma, P. Sharma, and A. K. Parashar, “Use of waste glass and demolished brick as coarse aggregate in production of sustainable concrete,” Materials Today: Proceedings, May 2022, doi: 10.1016/J.MATPR.2022.04.602.

[22] T. J. E. Miller, “Electronic Control of Switched Reluctance Motor”, Nownons Press 2000.

[23] Yadav, A., Chandra, S. (2021). Cascaded H-Bridge Based Multilevel Inverter for Power Quality Issues. In: Kumar, J., Jena, P. (eds) Recent Advances in Power Electronics and Drives. Lecture Notes in Electrical Engineering, vol 707. Springer, Singapore. https://doi.org/10.1007/978-981-15-8586-9_10.

[24] A. Agrawal, N. Sharma, and P. Sharma, “Designing an economical slow sand filter for households to improve water quality parameters,” Materials Today: Proceedings, vol. 43, no. xxxx, pp. 1582–1586, 2020, doi: 10.1016/j.matpr.2020.09.450.

[25] R. D. Zalke and A. G. Thosar, "C-dump converter for switched reluctance motor," 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2017, pp. 1733-1738, doi: 10.1109/RTEICT.2017.8256896.