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DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF ENGINEERING AND TECHNOLOGY, LAHORE

MESSAGE FROM THE VICE CHANCELLOR

University of Engineering and Technology is an institution, which has always nurtured its students to set and achieve lofty goals by providing them the freedom to polish their skill set through curricular and co-curricular activities. A commendable product of such efforts and skills is Elektron, a magazine by the Department of Electrical Engineering, produced by the students of the EED, UET Lahore. Elektron reflects the creative minds of the students of Electrical Engineering and their abilities to breathe life into their innovative ideas.

To make this magazine a constant source of guidance and inspiration for the masses, the work done by the team Elektron is indeed, highly appreciated and acknowledged. The efforts put forth by the team Elektron should serve as a motivation for other students of UET Lahore to embark upon similar initiatives. I wish them best in their future endeavors.

Stay Blessed.

Prof Dr. Nasir Hayat

Vice Chancellor

University of Engineering and Technology, Lahore

MESSAGE FROM THE CHAIRMAN

The aphorism “publish or perish” asserts the importance of publishing the scholarly work by the faculty and students. The Department of Electrical Engineering, historically, has been highly reputed for its outstanding undergraduate program. It has never been more important to involve undergraduate students in research. To publish the work carried out by under graduates has always been a challenge, due to the lack of availability of proper forum of this purpose, This is no more a limitation due to the introduction of the Elektron magazine. The Elektron team has put an extensive effort to make the idea a realization. The Elektron provides an excellent opportunity to both undergraduate as well as graduate students to publish their work. I believe this initiative will go a long way and will be pivotal in defining the careers of many.

Prof Dr. Muhammad Tahir

Chairman
Department of Electrical Engineering
University of Engineering and Technology,
Lahore

MESSAGE FROM THE EDITOR-IN-CHIEF

In Pakistan, the students at the pre-university level are often curious about opting their areas of professional education. However, it is observed that the students at those levels do not have access to the relevant knowledge to help make their minds taking suitable decisions. Elektron magazine is an effort of the Department of Electrical Engineering of UET Lahore, to remove this knowledge deficit of the pre-university students.

Especially, this magazine is an attempt to provide some knowledge to both the foundations and advances of the domain of science and engineering, in general, and electrical engineering and its applications, in particular. Link among religion, philosophy and science is another relevant area of study, published under the scope of this magazine. Other than helping pre-university students, Elektron is also publishing articles to enhance the knowledge of early semester students of electrical engineering, professional scientists, engineers, specially, electrical engineers, and of the other readers interested in learning and knowing about foundations and advances of science and engineering.

Elektron invited the articles with very broad scope, but the preferred areas of interest are, but not limited to

- Religion and Science Contribution of Muslims in the Field of Science
- Science and Philosophy (a union)
- Technical Innovations in Electrical and Electronics Engineering
- Engineering Mathematics
- Engineering Protocols and Ethics
- Engineering Book Reviews
- Works of a Renowned Researcher
- Engineering Case Studies

I hope, this issue of Elektron will also gain your attention and appreciation.

Dr. Muhammad Salman Fakhar

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

وَٱتَّقُواْ يَوۡمٗا لَّا تَجۡزِي نَفۡسٌ عَن نَّفۡسٖ شَيۡـٔٗا وَلَا يُقۡبَلُ مِنۡهَا
عَدۡلٞ وَلَا تَنفَعُهَا شَفَٰعَةٞ وَلَا هُمۡ يُنصَرُونَ ١٢٣ وَإِذِ ٱبۡتَلَىٰٓ
إِبۡرَٰهِـۧمَ رَبُّهُۥ بِكَلِمَٰتٖ فَأَتَمَّهُنَّۖ قَالَ إِنِّي جَاعِلُكَ لِلنَّاسِ إِمَامٗاۖ
قَالَ وَمِن ذُرِّيَّتِيۖ قَالَ لَا يَنَالُ عَهۡدِي ٱلظَّٰلِمِينَ ١٢٤

And guard yourselves against the Day when no soul will be of any help to another. No ransom will be taken, no intercession accepted, and no help will be given. ⌜Remember⌝ when Abraham was tested by his Lord with ⌜certain⌝ commandments, which he fulfilled. Allah said, “I will certainly make you into a role model for the people.” Abraham asked, “What about my offspring?” Allah replied, “My covenant is not extended to the wrongdoers.”
(QS. Al-Baqarah : 123-124)

TABLE OF CONTENTS

COMPUTER USING MEMORY
By Rehan Naeem — 1

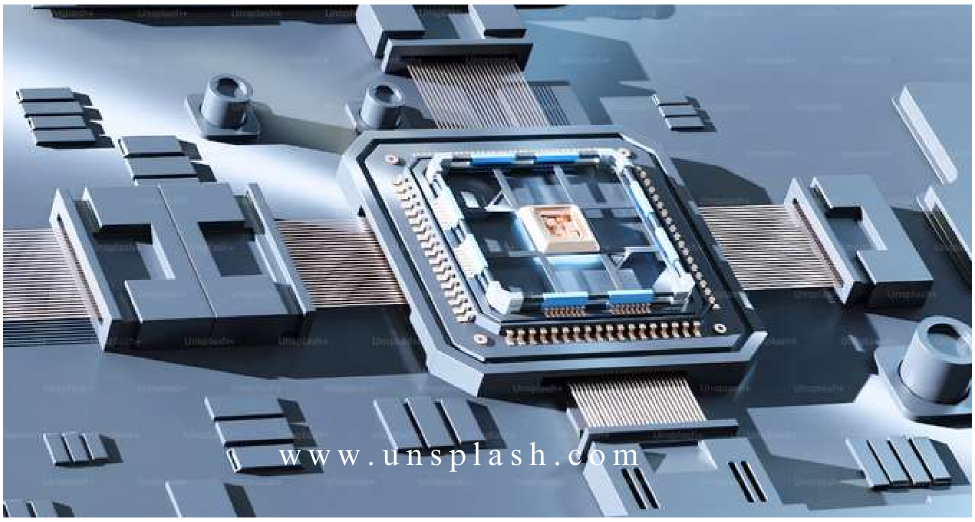
OPTIMIZING INSULATION FOR 35-KV SUPERCONDUCTING CABLES:
A Study of Polypropylene Laminated Paper
By Rana Shaheer and Zhangpeng — 4

RENEWABLE ENERGY INTEGRATION
By Muhammad Salman — 9

IGNITE POSSIBILITIES – ENGINEERING THE CHANGE: TOWARDS A SUCCESSFUL FUTURE
By Pakistan Cables and IEEE UET Lahore — 11

ANTENNA AS SENSOR
By Muhammad Zeeshan Khan — 12

POWER QUALITY-PREVALENT ISSUES AND SOLUTIONS
By Farah Abdul Rehman — 14



COMPUTER USING MEMORY

ABSTRACT

Data, usually processed by the central processing unit (CPU), takes time to be processed in existing computer architectures. This article discusses ideas to reduce this time, called latency, to speed up processing. In particular, processing in memory, which is an exciting research area in the field of computer architecture, is discussed.

INTRODUCTION

A computer is a device that performs computations, processes data, and stores them for future use. The model used in most computers today is the Von Neumann model shown in Figure 1. The program counter (PC) supplies the address of the instruction to be executed to the Memory; the Memory then instructs the ALU, which performs computations on the data stored in the temporary registers (TEMP). Large data are stored in the memory. Most of the data, which is to be processed or on which computation is to be performed, are fetched from the Memory. Today's processors are fast enough to perform billions of computations per unit of time. The performance of the computer is not limited by the processor's computing power but rather by the Memory. In other words, Memory is the bottleneck in today's computer systems due to two main reasons:

- Memory takes time (high latency) to provide or store data.
- Data movement to and from Memory also consumes lot of energy.

Figure 2 shows that 16nJ energy is consumed during read/write operation to the DRAM memory, approximately 100 to 1000 times more than the energy consumed during the addition of two numbers.

A paradigm shift is needed to minimize data movement between the Memory and the processor and process the data where it resides the most, i.e. Process data In or near the Memory. The idea is to place a computing unit very close to the Memory or make the Memory capable of performing computations (Figure 3). Genome analysis, climate modelling, time-series analysis and consumer devices are some areas which could benefit from these PiM systems. This article is a summary of [2] and [3], which introduce the readers to the ways computations could be performed in or near the Memory. It also highlights the needs, challenges, and opportunities in adopting Processing in Memory (PIM) computing systems. They also discuss some

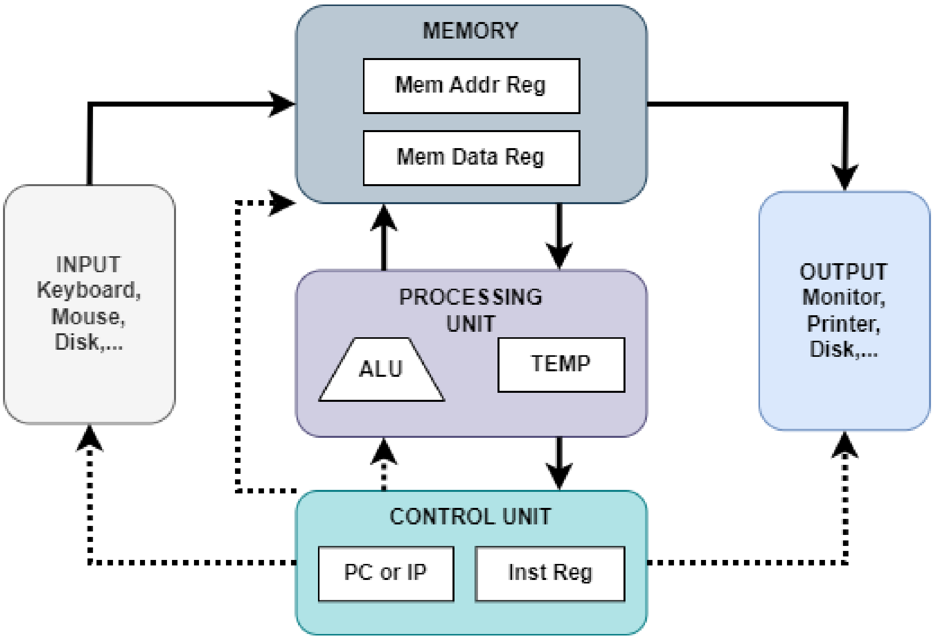


***Figure 1**. Von Neumann Model from [1]*

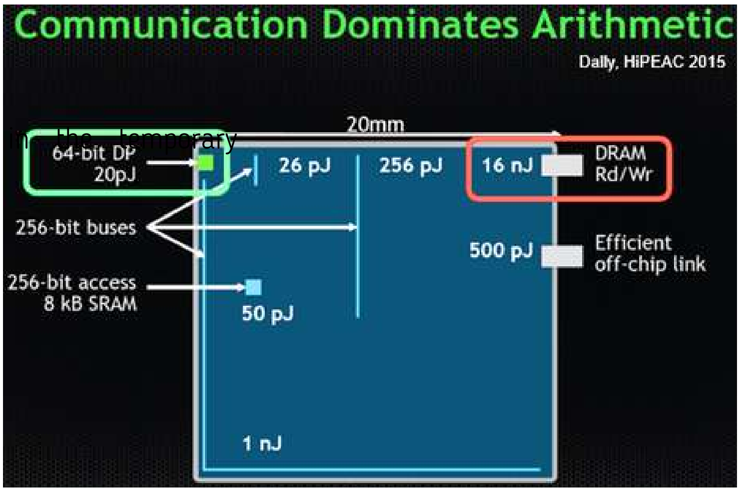


***Figure 2**. Communication vs Arithmetic Energy Consumption from [2]*

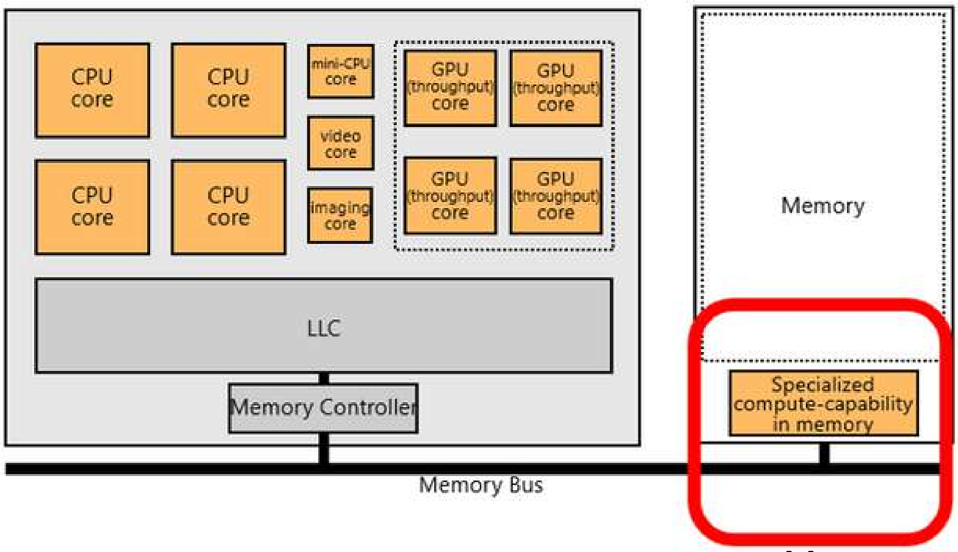


***Figure 3**. A Processing-in-Memory (PiM) Computing System from [2]*

cutting-edge research going on at the moment in this area.

PROCESSING IN MEMORY (PIM)

A. Data Copying and Initialization Using DRAM Memory (Row Clone)

Data could be copied inside the DRAM memory using a technique called row cloning [2]. Figure 3 shows the rows and columns of a DRAM. To copy data from row A to row B within the same subarray of a bank (Intra Sub Array Copy), row A is first activated and then transferred to the row buffer below. Row A is then deactivated while Row B

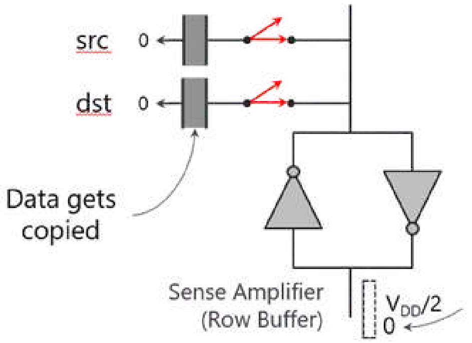


***Figure 5**. Sense Amplifiers to read a Bit Line from [2]*

is activated. The data is then transferred from the row buffer to row B. So, two activations are required to clone or copy a row. The row buffer uses sense amplifiers to read data from the row, as shown in the Figure. 5.

Data could also be transferred (Inter-Bank transfer) from one bank to another bank inside the Memory. Data could be copied from one sub-array of a bank to another sub-array of the same bank using interbank copying twice. Within a memory bank, data

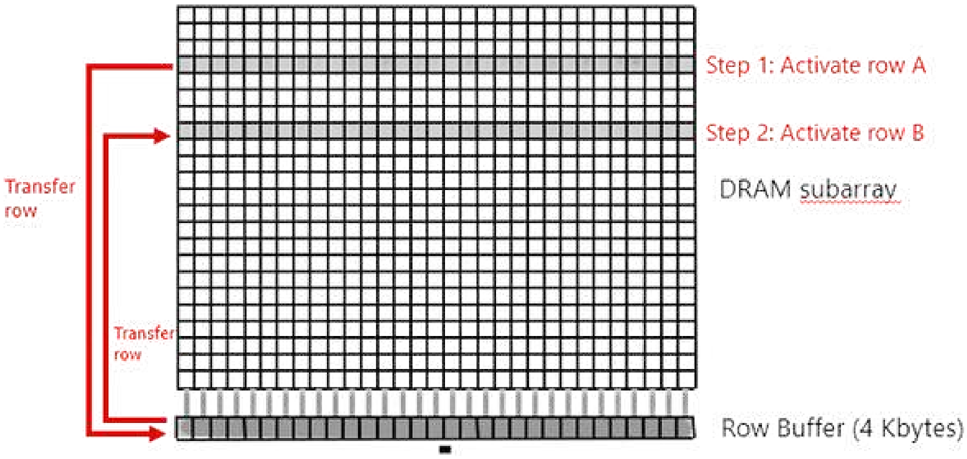


***Figure 4**. DRAM Arrays from [2]*

transfer between two sub-arrays is limited by the narrow bandwidth. Isolation transistors could be used to widen the data-path.

B. Bitwise Logical AND, OR and NOT Using DRAM Memory

Bitwise logical operations AND, OR and NOT could be implemented inside the DRAM memory. Consider three rows, A, B and C, each having a single capacitor-based storage cell in Figure 7. Initially, A=B=1 and C=0. A 1 means the capacitor is charged, and zero means the charge is absent. When all the switches are closed, the right

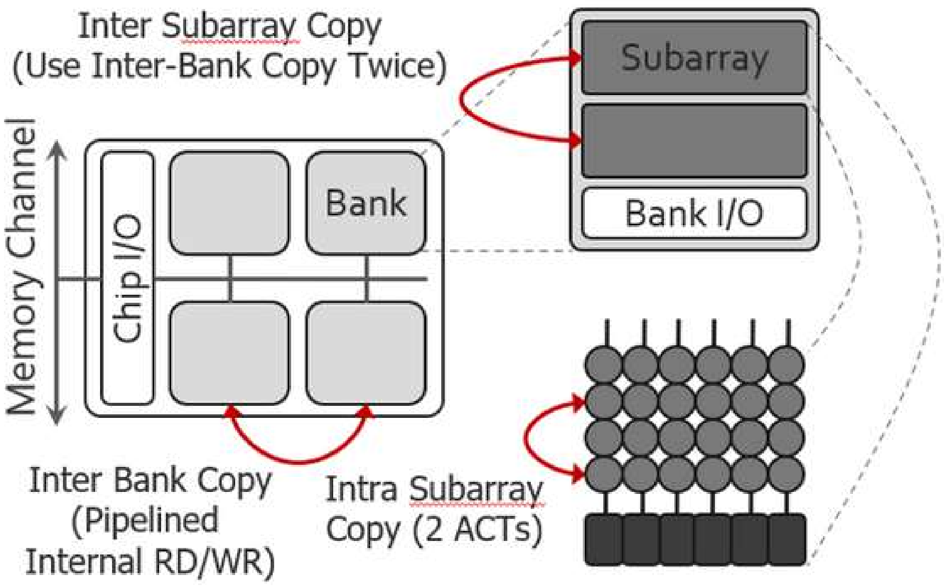


***Figure 6**. Intra Sub Array, Inter Bank and Inter Sub Array Copying from [2]*

output, due to which the cell C charges up fully. This whole operation, in essence, implements the logical operation C(A+B) + C′(AB), also known as majority-based computation, where the state of cell C determines the logical operation to be implemented, and the result of the operation is stored in cell C. Three rows (cells) need to be activated to perform and store the result of the logical computation. For more details see [2].

Bitwise logical NOT operation could be implemented using the arrangement shown in figure 6 but with the addition of a dual contact cell (DCC).

Assume the initial state 1 shown in Figure. 8. The bit to be inverted is

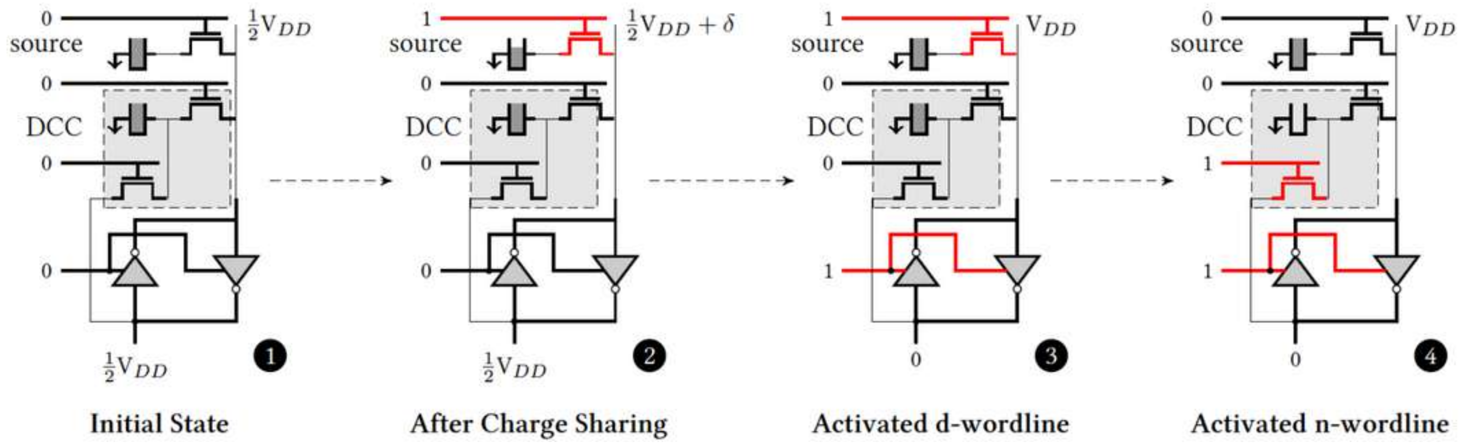


***Figure 8**. Logical NOT Operation Using DCC from [2]*

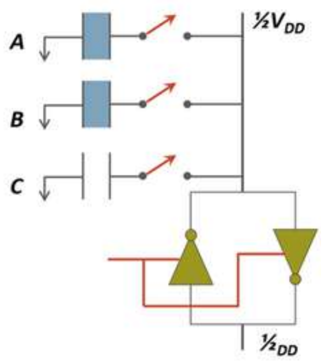


***Figure 7**. Triple Row Activation for Performing a Logical Operation from [2]*

inverter gets a high voltage at its input, thus giving low voltage to the left inverter's input, which in turn produces a robust high voltage at its stored in the topmost row. The result of the NOT operation is stored in the DCC's capacitor. State 2: First, the topmost transistor is enabled, thus increasing the input voltage to the right inverter. State 3: Both the inverters are enabled. The right inverter inverts the high voltage to low and provides it to the left inverter, which in turn provides a strong voltage VDD to the whole rightmost vertical line, also called a bit line. State 4: Now the topmost transistor is disabled while the transistor in DCC is enabled, thus discharging the capacitor in the DCC, which stores the result of the NOT operation.

CONCLUSION

Today's computing systems' performance is limited by Memory. There is a lot of data movement and energy wastage in traditional computing systems, hence prompting us to think about processing inside or near the Memory. This article introduced the readers to the needs, challenges, and opportunities in adopting processing in memory (PIM) computing systems. It also discussed some cutting-edge research going on at present in this area.

REFERENCES

[1] Mutlu, E., & Zürich. (2022). Digital Design & Computer Arch. Lecture 10a: Instruction Set Architectures II. https://safari.ethz.ch/digitaltechnik/spring2022/lib/exe/fetch.php?media=onur-digitaldesign_comparch-2022-lecture10a-isa-ii-afterlecture.pdf

[2] schedule [Computer Architecture - Fall 2022]. (n.d.). Safari.ethz.ch. Retrieved January 13, 2024, from https://safari.ethz.ch/architecture/fall2022/doku.php?id=schedule

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OPTIMIZING INSULATION FOR 35-KV SUPERCONDUCTING CABLES:
A Study of Polypropylene Laminated Paper

ABSTRACT

This paper focuses on investigating the insulation properties of 35-kV superconducting cable. To achieve this, the study first conducted experiments on the electrical insulation characteristics of Polypropylene Laminated Paper (PPLP), which provided information on the insulating strength in AC breakdown and lightning impulse breakdown based on the Weibull distribution. Using the parameters of PPLP, the researchers designed the insulation of the 35-kV superconducting cable and created model samples to test the insulation characteristics in AC breakdown and partial discharge inception trials. The results of the tests indicated that the design meets the national standard requirements for the insulation of 35-kV cable. This insulation design has significant practical implications for the application of superconducting cable and can be used as a reference for future studies. The paper uses the following keywords: insulation of 35-kV superconducting cable, Polypropylene laminated paper, partial discharge inception trial, and AC breakdown trial.

INTRODUCTION

In recent years, the second-generation high-temperature coated superconductors have made significant progress in terms of current-carrying and stability. With the improvement of the preparation technology of high-temperature superconducting materials, the economic performance of the second-generation high-temperature coated superconductors has been highlighted. It has been widely used in power systems, such as superconducting cables, superconducting current limiters, superconducting transformers and superconducting energy storage systems. The high-temperature superconducting cable uses the second-generation high-temperature coated superconductor as its conductor part. Compared with conventional cables, it has the characteristics of large transmission capacity, small loss, small footprint, and environmental friendliness. Mass [1, 2]. Therefore, the United States, Japan, South Korea and other countries are actively carrying out technical research on high-temperature superconducting cables.

In 2008, under the support of the US Department of Energy, the Phase I superconducting cable project of the Long Island Power Bureau completed the development of a 600 m long three-phase high-temperature superconducting cable and put it into operation at the Long Island Power Bureau—key technical issues in the manufacture and grid-connected operation of superconducting cables [3]. At the end of 2012, a 250 m high-temperature superconducting cable transmission test line with a rated voltage and current of 66 kV/200 MVA built in Yokohama in Japan realized grid-connected operation [4]. With the support of the Advanced Power System Application Superconducting Technology Development Plan implemented by the Korean Ministry of Science, Technology and Education, South Korea has completed the development of a 22.9 kV/50 MVA three-phase AC high-temperature superconducting cable and has already tested 250 kV high -temperature DC The insulation design of superconducting cables has been experimentally studied [5, 6].

Due to the problem of AC loss in high-temperature superconducting AC cables, and superconducting DC cables have extremely low loss, more compact structure, and larger transmission capacity than AC cables, so high-temperature superconducting DC cables have attracted more and more attention. It is expected to be widely used in power transmission, ship cables and new energy sources. High-temperature superconducting cables are developing in the direction of large length, high current, high voltage and high power. In order to obtain long-term safe and reliable superconducting DC cables, it is required that the high-temperature superconducting DC cables have reliable low-temperature and high-voltage insulation performance. Therefore, the research on the main body insulation of superconducting cables is particularly important.

The high-temperature superconducting cable system consists of a conductor part, a cooling part and an insulating part. The electrical insulation of the high-temperature superconducting cable is a composite insulation composed of insulating materials and liquid nitrogen. In the insulation design of high-temperature superconducting DC cables, PPLP (Polypropylene laminated paper) is widely used. It has good impregnation performance and strong insulation properties, so it has been widely studied. In this paper, the insulation performance of the insulating material PPLP was tested first, and then, according to the test results, the main insulation and the winding insulation of the 35 kV low-temperature insulated superconducting cable were designed. A cable model sample was made, and the partial discharge and power frequency withstand voltage electrical insulation tests were carried out on the sample. The experimental results prove the reliability of the insulation design of the 35 kV low-temperature insulated superconducting cable.

BREAKDOWN STRENGTH TEST OF INSULATING MATERIAL PPLP

A. Preparation of test samples

The insulating material used in this high-temperature superconducting insulation is PPLP-HTS-125 from Sumitomo Corporation of Japan. The main parameters are shown in Table 1. A length of 600 mm and an outer diameter of 20 mm is selected as the skeleton. Two layers of carbon paper are wound on the copper tube to uniform the electric field, and then seven layers of PPL P are wrapped on the carbon paper in a seam-folding manner. Outside the main insulation, the stress cone insulation is added at both ends of the sample to ensure that the breakdown occurs only in the main insulation layer. And install epoxy resin rings to protect the electrodes at both ends of the stress cone. Two layers of carbon paper are tightly wrapped around the main insulation and the stress cone augmented insulation, and the metal mesh is wrapped around the carbon paper to lead out the grounding wire. The fabricated sample is shown in Figure 1.

***Table 1**. Main parameters of PPLP-HTS-125*

PROJECT		Unit	PPLP-HTS-125
THICKNESS		um	125±10
BULK DENSITY		g/m^3	0.90±0.10
PULL	Portrait	N/15mm	M in. 89
	Horizontal		M in. 2.0
HUMIDITY		%	Max 7.0

B. Breakdown strength test results of insulating material PPLP

The AC breakdown test and lightning impact test were carried out on the manufactured test samples, and the average breakdown field strength, the maximum breakdown field strength and the minimum breakdown field strength of the PPLP used in the liquid nitrogen environment were obtained. Probability statistics based on the three-parameter Weibull distribution were performed on the data obtained from the two experiments, and the distributions are shown in Figure 2 and Figure 3, respectively.

***Figure 1**. Test sample of insulating material PPLP insulation performance*

35 KV LOW-TEMPERATURE INSULATED SUPERCONDUCTING CABLE INSULATION DESIGN

A. Main insulation design of superconducting cable

Superconducting cables need to consider partial discharge field strength, power frequency withstand voltage field strength and lightning impulse field strength. According to the national standard "GB/T 12976.3-2008, rated voltage 35 KV (U_m=40.5 KV) and below paper insulated power cables and

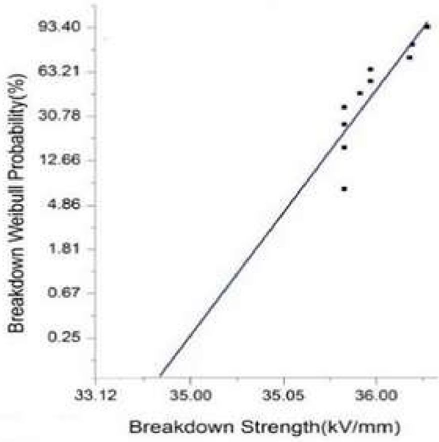

***Figure 2**. Weibull distribution diagram of AC breakdown test*

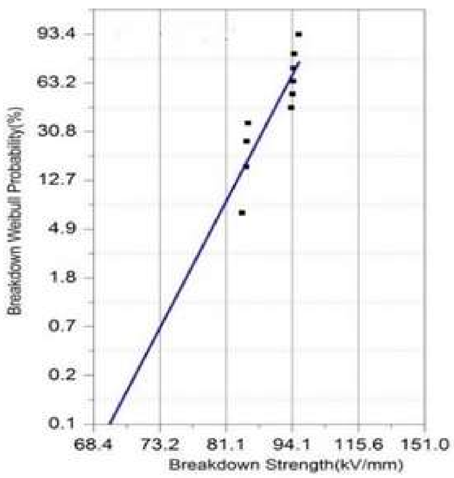

***Figure 3**. Weibull distribution diagram of lightning impulse test*

accessories Part 3", for 35 KV cables, test voltage U_o=21KV, industrial Frequency withstand voltage test voltage U_{ac}=2.5, U_o=52.5KV, withstand time 5 minutes. The peak voltage of the lightning impulse withstand voltage test is 200 KV, and it should be able to withstand the positive and negative polarity peak voltages ten times without breakdown. Conduct a partial discharge test according to GB/T 3048.12-2007, and the test sensitivity should be 5 PC or better. The test voltage should be gradually increased to $2U_o$=42 KV and kept for 10s, then slowly decreased to $1.73U_o$, at $1.73U_o$ There shall be no detectable discharge from the cable under test exceeding the declared test sensitivity [8].

Power frequency withstand voltage field strength E_{ac}= 34.75 kV/mm and the lightning impulse field strength E_{imp}= 69.42 kV/mm obtained from the PPLP insulation performance test results. According to the literature, the partial discharge field strength is taken as E_{pc} = 22 kV/mm [9].

According to the calculation formula:

$$t = r_c \left[e^{\left(\frac{U}{r_c E}\right)} - 1 \right]$$

Among them, t is the insulation thickness, the radius of the superconducting cable skeleton, U is the test voltage, and E is the test field strength.

According to the calculated value, the thickness of the insulation with the largest lightning impact is taken as the thickness of the main insulation. Considering the actual production and application of the cable, the thickness of the main insulation is t = 4mm.

B. Design of superconducting cable stress cone

The cable terminal is the weak link compared with the cable body. Because the cable shielding layer is cut off inside the cable, the electric field distribution at the cable terminal is much more complicated than that of the cable body. The electric field not only has a component perpendicular to the direction of the insulating paper but also a component along the direction of the insulating paper, and the electric field distribution along the length of the cable is also different. Uniform, relatively concentrated on the edge of the shielding layer, and the electric field intensity is the largest at the interruption of the shielding layer. The stress cone is a cone added at the interruption of the cable shielding layer. The cone can relieve the concentration of the electric field, optimize the distribution of the electric field, and ensure that the cable insulation is the effect of being destroyed [10].

The maximum allowable working field strength in the terminal joint is lower than that of the cable body, generally 60-70% of the cable body. We are taking into account the wire effect and roughness of the surface of the conductor layer. Therefore, when designing, the maximum working field strength on the surface of the conductor layer is taken as about 45-60% of the maximum working field strength of the cable body.

According to the calculation formula:

$$E_1 = \frac{U}{r_c \times ln\left(\frac{R}{r_c}\right)}$$

$$\Delta t = r_c \times e^{\left(\frac{U}{E_n \times r_c}\right)} - R$$

Where is the thickness of the stress cone, r_c is the radius of the superconducting cable skeleton, and E_n is the maximum field strength on the surface of the conductor layer, which is taken as E_n= 0.5E1 in this design. U is the test voltage, and R is the radius of the superconducting cable, taking into account the main insulation.

Considering the actual cable production after calculation, take the stress cone thickness Δt = 6mm. The stress cone is designed according to its surface axial field strength equal to (or less than) the allowable maximum axial field strength. The maximum allowable axial field strength of the insulating layer at the connection is generally taken as 1/10 to 1/20 of the maximum working field strength of the cable body. The axial length of the stress cone can be obtained:

$$L_k = \frac{U}{E_t} \times ln\left(\frac{ln\left(\frac{R_n}{r_c}\right)}{ln\left(\frac{R}{r_c}\right)}\right) = 49.1057$$

(Mm). Similarly, considering the actual production of cables, take the axial length of the stress cone = 50mm. The simulations of the unstressed cone and the stressed cone of the cable sample are shown in Figure. 4 and Figure. 5, respectively.

Figure 4. *Simulation diagram of electric field strength of unstressed cone*

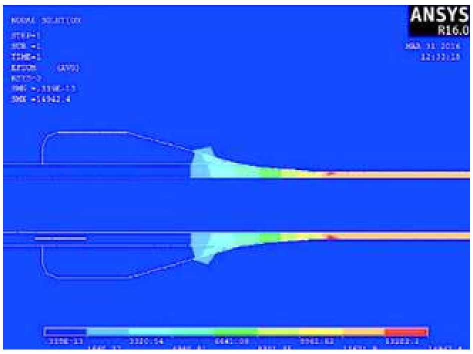

Figure 5. *Simulation diagram of electric field strength with stress cone*

Comparing Figure 2 and Figure 3, it can be seen that after adding the stress cone, the electric field intensity at the cut-off point of the shielding layer is much smaller than that at the cut-off point of the shielding layer without adding the stress cone.

ELECTRICAL INSULATION TEST OF 35 KV LOW-TEMPERATURE INSULATED SUPER-CONDUCTING CABLE

A. Preparation of cable model samples

The test samples for this test are made by winding machines of Nanjing Baiyun Electric High Voltage Bushing Co., Ltd. in order to ensure the winding tension and sample quality. Put the cut PPLP paper disc into the oven for 24 hours to fully dry before winding. Afterwards, according to the designed cable parameters, the samples are also made by the seam-wrapping process.

B. Partial discharge test

Since the sample is wound by seam wrapping, there will inevitably be small gaps in the insulating layer, and these small gaps in the insulating layer are likely to cause partial discharge. According to the boundary value principle of the electric field

$$e_1 \times E_1 = e_2 \times E_2$$

The dielectric constant of nitrogen in the air gap of the low-temperature insulating layer is close to 1. The dielectric constant of PPLP is 2.21, so the electric field in the atmosphere is more than twice that of the surrounding insulating materials. The electric strength of air is much smaller than that of PPLP. Therefore, when the insulation withstands voltage, the pores or air gaps in the insulation layer are called electric field concentration points. At a voltage far lower than the insulation breakdown strength, the first breakdown produces partial discharge. Although the cable immersed in liquid nitrogen increases the partial discharge inception voltage, the air gap will not be filled by liquid nitrogen, so measuring the partial discharge of the cable is of great significance to understanding its insulation performance [7].

The test was carried out in Nanjing

Baiyun Electric's shielding laboratory. Due to the need to provide a low-temperature environment, the test adopts a high temperature of 2.2 m Dewar, a diameter of 1 m, the distance from the flange of the high-voltage bushing to the equalizing ball at the end of the high-voltage bushing is 1.32 m, to ensure that the bottom distance meets the electrical insulation requirements. The Dewar used in the test is shown in Figure 6.

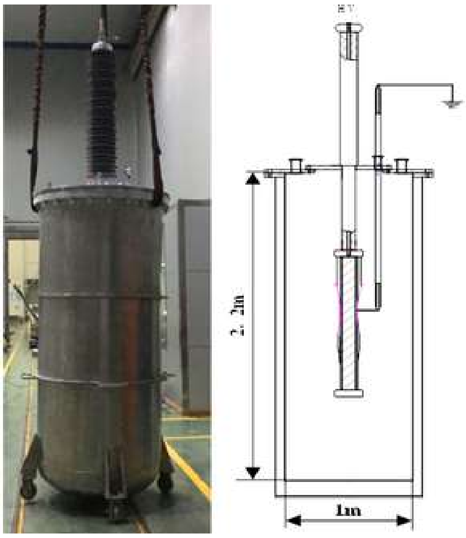

Figure 6. *Schematic diagram of cryogenic Dewar structure*

Before the experiment, the Dewar was evacuated, filled with liquid nitrogen, and the sample was completely immersed in liquid nitrogen and stood still for at least 4 hours to ensure that the sample was fully cooled. The partial discharge test site is shown in Figure 7.

Figure 7. *Partial discharge test site*

Apply high potential: One end of the sample is connected to the lower end of the 110 kV high-voltage bushing by a processed turnbuckle and shares a pressure-equalizing ball with the high-voltage bushing, and the high potential is applied to the skeleton during the test.

Zero-potential lead-out: 2 layers of carbon paper are tightly wrapped around the main insulation and the stress-cone winding insulation , and

Figure 8. *Diagram of the improved sample device*

the metal grounding grid is wrapped around the carbon paper to lead out the grounding wire. Wrap crepe paper around the outside of the metal mesh to eliminate the tip of the metal ground mesh.

After switching on, the partial discharge detection instrument will show that the partial discharge is severe. Nanjing Baiyun Electric High Voltage Bushing Co., Ltd. often tests the partial discharge of the bushing when inspecting the quality of the high-voltage bushing. Therefore, their technicians have valuable practical experience and suggested that even if the copper grid of the metal grounding grid is wrapped in crepe paper, the impact on the tip is still serious. We should use aluminium foil instead, which is much smoother than the copper grid. Moreover, we processed a device similar to a pressure-equalizing ring to shield the outside. The whole device is a hollow cylinder cut in half to cover the sample. A small hole is opened on the side of the device to lead out the grounding wire. After the device is installed, the sample is shown in Figure 8. According to the experimental standard, first, gradually increase the pressure to 2U 0, keep it for 10s, and record the readings of the partial discharge detector. After it drops to 1.73U0, record the reading of the partial discharge detector. Change different samples to repeat the test, and the data after detecting multiple samples are listed in Table 2.

From the table data, the partial discharge detection results of the designed insulation are all less than five PCs, which meets the requirements of the national standard.

Figure 9. *Breakdown diagram of power frequency withstand voltage test sample.*

C. Power frequency withstand voltage test

The power frequency withstand voltage experiment of insulation performance at low temperatures is the same as the partial discharge experiment by applying high potential and zero potential. In the experimental test, the voltage was first raised to the the standard value of 52.5 kV for 5 minutes and then dropped to zero, and then the voltage was raised to 52.5 kV for 5 minutes without breakdown. Each point was tested three times, and no breakdown occurred, indicating the point was efficient. Afterwards, the experimental test was carried out in steps of 5 kV starting from 55 kV until the sample broke down. The sample breakdown and test results are shown in Figure 9 and Figure 10, respectively.

Table 1*. Main parameters of PPLP-HTS-125*

SAMPLE NUMBER	DETECTION VOLTAGE (kV)	PARTIAL DISCHARGE DETECTION (PC)
1	42.09	4.7
	36.76	3.0
2	42.65	3.0
	38.17	1.7
3	42.09	2.0
	36.20	2.0
4	42.65	2.7
	36.20	2.0
5	42.09	4.0
	36.67	4.0
6	42.09	4.0
	36.20	2.7
7	42.65	3.0
	38.17	2.0

According to the aforementioned national standards, the 35 kV paper insulation standard is 2.5U 0 =52.5 kV for 5 minutes, as shown in the green column in the chart. The blue column indicates that the actual voltage is applied to this value and endured for 5 minutes without breakdown. It can be seen from the chart that the design value meets the standard and has a certain margin.

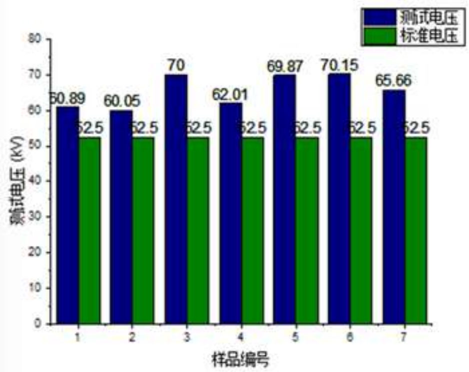

Figure 10. *Test results of power frequency withstand voltage test.*

CONCLUSION

In this paper, the insulation performance of insulating material PPLP is tested and studied, and according to the Weibull distribution, the power frequency withstand voltage insulation field strength of insulating material PPLP is 34.75 kV/mm. The lightning impulse insulation field strength is 69.42 kV/mm. According to the dielectric strength of PPLP, the insulation design of 35kV low-temperature insulated superconducting cable is carried out, including the main insulation of the cable and the stress cone design.

Model cables were made according to the designed parameters, and the design values were tested and verified in Nanjing Baiyun Electric High Voltage Bushing Co., Ltd. The test data obtained through the partial discharge test and the power frequency withstand voltage test show that the designed cable insulation meets the requirements of the national stand this basis, keeping a reasonable margin and for 35kV paper-insulated cables. On is an important reference for the practical application of superconducting cables.

REFERENCES

[1] Maguire, J. F., Yuan, J., Romanosky, W., Schmidt, F., Soika, R., Bratt, S., ... & Welsh, T. E. (2010). Progress and status of a 2G HTS power cable to be installed in the Long Island Power Authority (LIPA) grid. IEEE Transactions on Applied Superconductivity, 21(3), 961-966.

[2] Ohya, M., Yumura, H., Masuda, T., Amemiya, N., Ishiyama, A., & Ohkuma, T. (2011). Design and evaluation of 66 kV-class HTS power cable using REBCO wires. Physica C: Superconductivity and its applications, 471(21-22), 1279-1282.

[3] Chinese National Standards. (2008). GB/T 12976.3-2008, Paper insulated power cables and their accessories for rated voltages up to and including 35 KV (Um=40.5 KV) Part 3.

[4] Yagi, M., Mukoyama, S., Mitsuhashi, T., Jun, T., Liu, J., Nakayama, R., ... & Maruyama, O. (2013). Design and evaluation of 275 kV-3 kA HTS power cable. Physics Procedia, 45, 277-280.

[5] Sohn, S. H., Lim, J. H., Yim, S. W., Hyun, O. B., Kim, H. R., Yatsuka, K., ... & Hwang, S. D. (2007). The results of installation and preliminary test of 22.9 kV, 50 MVA, 100 m class HTS power cable system at KEPCO. IEEE Transactions on Applied Superconductivity, 17(2), 2043-2046.

[6] Kim, W. J., Kim, H. J., Cho, J. W., Lee, H., Choi, Y. S., & Kim, S. H. (2015). Insulation characteristics of PPLP and design of 250 kV class HTS DC cable. IEEE Transactions on Applied Superconductivity, 25(3), 1-4.

[7] Kim, H. J., Kwag, D. S., Cho, J. W., Seong, K. C., Sim, K. D., & Kim, S. H. (2005). Insulation studies and experimental results for high Tc superconducting power cable. IEEE transactions on applied superconductivity, 15(2), 1727-1730.

[8] Huang, X., Wu, C., Fang, J., et al. (2012). Design of Stress Cone Structure Based on High Temperature Superconducting Cable Termination. Superconducting Technology, 40(4).

[9] Song, H., Brownsey, P., Zhang, Y., Waterman, J., Fukushima, T., & Hazelton, D. (2012). 2G HTS coil technology development at SuperPower. IEEE Transactions on Applied Superconductivity, 23(3), 4600806-4600806.

[10] Du, B., Xing, Y., Fu, M., et al. (2015). Research Status of High Temperature Superconducting Cables and Their Low Temperature Insulation. China Southern Power Grid Technology, 9(12), 29-30.

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RENEWABLE ENERGY INTEGRATION

ABSTRACT

Fluctuations in the global environment, nuclear dangers, power grid interruptions, and rising fuel prices stimulate demand to produce power by utilization of sustainable power. Many people nowadays want to stay and collaborate in sustainable systems, such as renewable energy. This study concentrates on developing a hybrid energy system that generates and delivers electrical energy to the end-user when utility grid power is insufficient to support the customer's demand for various reasons. The means to generate electricity from solar and wind are different and independent. However, when they integrated, they aided in fulfilling the load requirement. Using this idea, the Renewable energy integration model is developed using solar, wind and grid. A grid-tied hybrid energy system's reliability factor is higher than a conventional renewable-based energy system. Renewable energy sources are being replaced with renewable energy with grid ties due to their higher reliability. Implementing hybrid energy sources will boost land productivity, aid in integrating and utilizing electrical power, and decrease carbon's environmental impact. Systems involving diverse energy sources are more effective than traditional utility grids.

INTRODUCTION

The most important aspect is the abundance of fossil fuel energy. There are energy sources that considerably lessen their negative environmental effects. Most investments in renewable energy go towards the staff and materials needed to build and run the plants, not towards importing costly energy. The advancement of mass communication technology has made people more aware of the risks associated with combustion. Fossil energy sources, like lignite, natural gas, and oil, require pricy extraction and extremely risky drilling and refining. The cost of electricity will increase in tandem with demand. The price of power can be stabilized by renewable energy. The reason for this is that price is solely determined by initial investment.

Additionally, it is unaffected by changes in the cost of natural fossils. Wind and sunlight are easy and safe sources of renewable energy. Renewable energy is significantly friendlier in the environment. The cost and installation comparison of the wind and the solar are given below, respectively;

A renewable energy source, photovoltaic (PV), has great potential. Once built, PV-generating systems employ solar radiation to generate energy without releasing greenhouse gases. The authors implemented an approach to track the maximum power for the shaded area on the PV due to cloudy weather. Traditional MPPT approaches upgraded MPPT techniques, and artificial intelligence-based MPPT strategies to deal with PSCs are grouped into three categories to clearly and progressively clarify the working principle and the benefits and drawbacks of the various proposed techniques [3].

In this study, electrical energy is generated using solar photovoltaic generators and wind turbines. This article also looks at the hybrid and electric power technology for the selected power system for Debre Berhan City. The developed hybrid system is connected to the grid to provide the load. The components of the power system and the hybrid energy system network are modelled using MATLAB software [1].

This study examines the design of a grid-connected wind-solar cogeneration system that uses DC-DC boost converters and full-scale back-to-back voltage source converters (VSC). To increase the effectiveness of energy

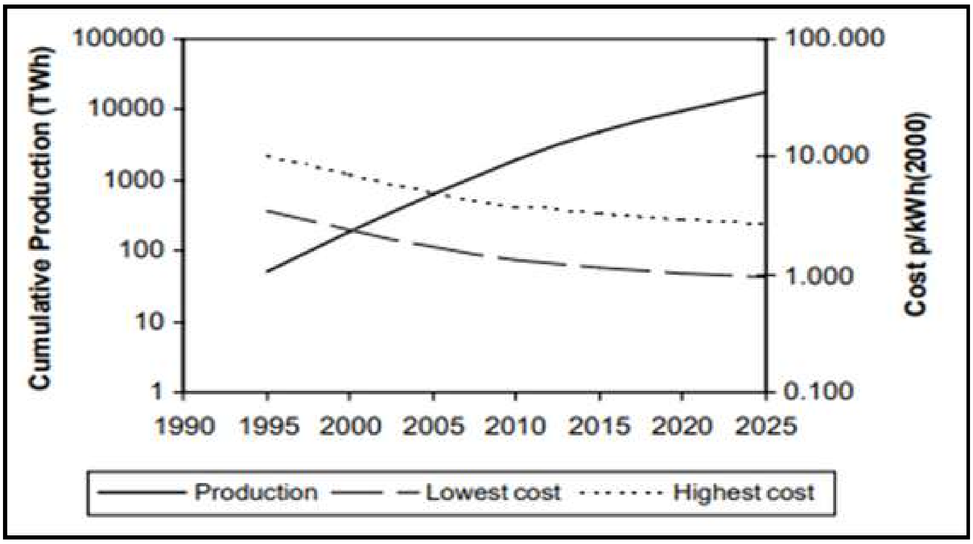

Figure 1. *Reduction in cost and growth in installation capacity for wind [2].*

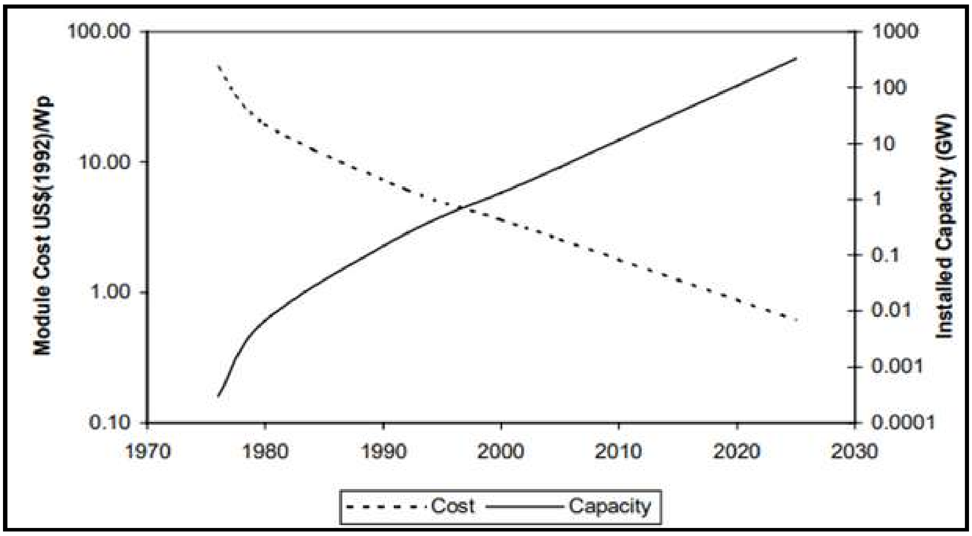

Figure 2. *Reduction in cost and growth in installation capacity for solar PV [2].*

extraction, new perturb and observe (P&O) and incremental conductance (INC) based MPPT algorithms are created [4].

PROPOSED MODEL

In this study, a DFIG will transform wind energy into electricity with a solar photovoltaic system to the Dc/DC converter to create a photovoltaic wind energy conversion system as shown in Figure 3.

As solar power depends on solar radiation and module temperature, the output voltage changes whenever these quantities change at each instant. The PV module cannot be directly linked to the DC bus of the back-to-back converter since it must always remain constant. It will be necessary to use a step-up converter to raise the solar photovoltaic module's voltage level and synchronize that with the DC/DC converter. A solar PV system is modelled in a Simulink using metaheuristic-based MPPT. To choose the best MPPT metaheuristic algorithm for an isolated solar PV system, a Simulink simulation of the system is constructed and connected to the boost converter.

The wind turbine model comprises a DFIG machine with the equivalent torque of wind speed. Different metaheuristic algorithms are used to maximize the amount of energy generated. Here, the model's variable parameters will be held constant, and conventional algorithms will be changed while the wind speed remains constant. Thus, observing the power generated through each approach determined the optimal algorithm for the hybrid wind-solar conversion system.

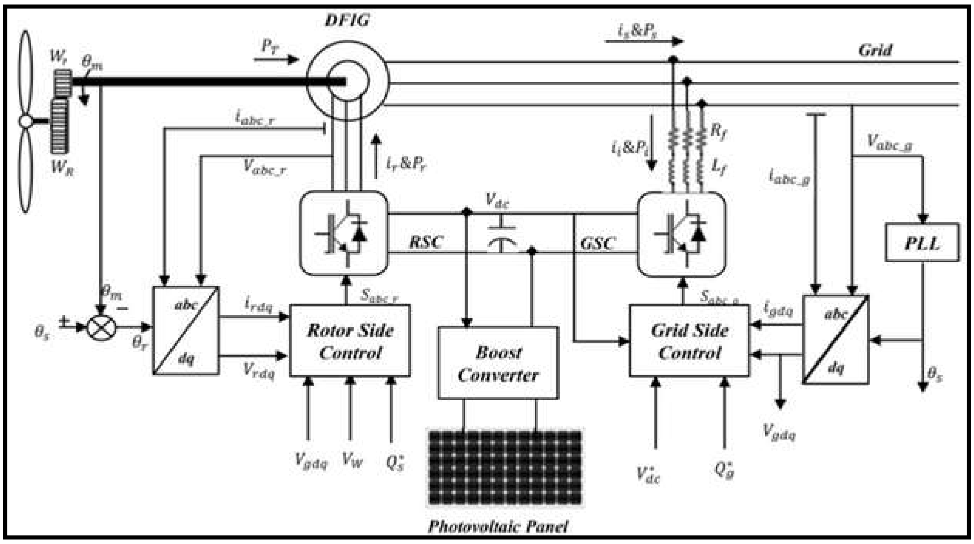

Figure 3. *Hybrid Energy System*

The MATLAB Simulink environment simulates the proposed approach, which comprises a wind-solar hybrid model. Efficiency and power analysis will be implemented in MATLAB/Simulink. Rotor side Converter, Grid side converter, MPPT controller for the photovoltaics island mode, and MPPT for the wind energy in a hybrid energy model are designed.

CONCLUSION

The benefit of the solar PV model coupled with the back-to-back converter's DC link will be discussed. It will also address the decreased reliance on the grid, supplying extra electricity to the grid. Additionally, MPPT algorithms are crucial in boosting the entire system's efficiency. The results of this study will help the industry to choose the use of hybrid energy systems to enhance power reliability. Researchers and developers working in this field would greatly benefit from this research, which also contains insightful information about advancing renewable-based hybrid energy systems to increase system efficiency and sustainability.

REFERENCES

[1] Bayu, A., Anteneh, D., & Khan, B. (2022). Grid integration of hybrid energy system for distribution network. Distributed Generation & Alternative Energy Journal, 667-675.

[2] Gross, R., Leach, M., & Bauen, A. (2003). Progress in renewable energy. Environment international, 29(1), 105-122.

[3] Omar, F. A., Pamuk, N., & KULAKSIZ, A. A. (2023). A critical evaluation of maximum power point tracking techniques for PV systems working under partial shading conditions. Turkish Journal of Engineering, 7(1), 73-81.

[4] Sadiq, R., Wang, Z., & Chung, C. Y. (2023). A multi-model multi-objective robust damping control of GCSC for hybrid power system with offshore/onshore wind farm. International Journal of Electrical Power & Energy Systems, 147, 108879.

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IGNITE POSSIBILITIES - ENGINEERING THE CHANGE: TOWARDS A SUCCESSFUL FUTURE

An event organized by Pakistan Cables & supported by IEEE UET Lahore

The seminar, titled "**Ignite Possibilities - Engineering the Change: Towards A Successful Future**" was organized through the collaborative efforts of IEEE UET Lahore and Pak Cables Limited. As a talk series, it brought together esteemed speakers from various fields to shed light on pressing issues such as climate change, sustainability, and individual commitments towards a greener future.

The seminar commenced with a recitation from the Holy Quran, followed by **Mrs. Mariam Durrani**, Director Marketing of Pak Cables, who introduced Pak Cables and provided a historical overview through a short video that celebrated the company's 70 years of excellence. As the head of marketing, she emphasized corporate responsibility and highlighted Pak Cables' commitment to environmental sustainability.

The talk series began with **Mr. Raza Ali Dada**, a seasoned architect currently serving as the Managing Partner at Nayyar Ali Dada and Associates. He delved into the foundations of building and structure, discussing the impact of pollution and emphasizing sustainability. Mr. Dada stressed the delicate balance of the ecosystem and the disastrous consequences for both the environment and human life if care is not taken. He encouraged students to engage in communal efforts to strive for positive change.

Proceeding with the talks, **Mrs. Imrana Tiwana**, a Sustainable Development Specialist and Urbanist, discussed the importance of mapping cities and shared her own experiences. Tiwana highlighted the need for independent thinking in addressing dysfunctional aspects of our world, including water scarcity, increased construction material usage, deforestation, and hunger. The discussion then shifted towards Pakistan's contributions and inequities, emphasizing the need for equitable distribution and sustainable development.

The third speaker, **Ms. Hafsa Naeem**, Country Director for Bondh-e-Shams, shared details about the Solar Water Project in which the company is involved. She emphasized innovative solutions like the Oasis Box to purify water, showcasing the power of sustainable initiatives in addressing environmental challenges.

Dr. Habib-ur-Rehman, Vice Chancellor UET Lahore, thanked the speakers for addressing the climate issue and providing insights into tackling this global challenge. He expressed gratitude to Mr. Fahd Kamal Chinoy, CEO of Pak Cables, and Dr. Muhammad Tahir, Chairman of the Department of Electrical Engineering, for their contributions to the seamless organization of the seminar and making the talk series possible. **Mr. Arshad Shafiq**, Director Operations for Pak Cables, presented the CO2 impact graph, highlighting Pakistan's vulnerability to climate change. He discussed Pak Cables' commitment to sustainability, showcasing the Nooriabad factory's efficiency improvements through the use of solar panels and the implementation of the ambitious urban forest project, which aimed at planting 47,000 trees by 2021. **Mr. Fahd** shared his personal experiences with how Pak Cables was affected by climate change and outlined the proactive measures taken in response. He expressed gratitude for the collaborative efforts and encouraged collective action for a sustainable future.

The event concluded with an award ceremony where Mr. Fahd awarded shields to the speakers, and a commemorative photo was taken. The event served as a catalyst for future discussions and initiatives aimed at building a more resilient and sustainable world.

ANTENNA AS A SENSOR

ABSTRACT

An antenna acts as a unique device that can send out or catch electromagnetic (EM) waves in the air. Think of it as a crucial player in the operation of things like phones and WiFi. This article explores the diverse roles of antennas beyond just serving phones. Antennas can perform fascinating tasks such as on-body applications, on-chip functions, measuring strain with RFID technology, and even harvesting energy from EM waves. Explore the fascinating world of antennas and learn about the incredible things they can accomplish beyond using them in wireless communication equipment.

INTRODUCTION

Over the past few years, the quantity and capabilities of sensor-based systems have increased dramatically. The advancements in the many technologies utilized in these systems have coincided with this enormous expansion. The various subfields of nanotechnology have opened up a wide range of new structures and technologies for use in sensing devices, enabling the measurement of various intriguing magnitudes. Most of these new sensing technologies promise to be compatible with standard microelectronics, such as CMOS technologies or something similar, in order to completely integrate the sensing element with the bias, conditioning, and processing circuits and produce very "smart" systems [1]. Fortunately, various antennas with various characteristics and topologies have also emerged as personal communication systems such as WiFi and WiMAX have progressed. Printed antennas are the preferred choice for wireless sensor applications, including intelligent sensors and wireless sensor networks (WSNs), due to their numerous benefits over alternative types of antennas. Their low weight, low profile, and compatibility with almost all-dielectric substrates are advantages that may be used to improve the characteristics of a particular sensor application, such as complete integration [2].

ON-BODY ANTENNAS

It was recently determined that on-body communication systems must be improved as a distinct application sector requiring particular antenna requirements [3]. This paradigm can incorporate medical sensor networks, emergency response personnel, and short-range personal communications. Few-meter radio lines are typically taken into consideration in such situations [4]. Printed antennas have shown to be dependable in these applications when it comes to particular issues like environmental dispersion or human dynamics. It is important to differentiate between wearable and implanted antennas.

ON-CHIP ANTENNAS

The need for extremely compact and affordable wireless modules has increased exponentially, placing a strong demand on system-on-a-chip (SoC) technology. An essential part of SoC-based wireless communication systems, on-chip antennas (OCAs) have become a prime contender for many exciting uses, particularly at millimetre wave and terahertz frequencies. Additionally, OCAs facilitate low-power and compact wireless sensor networks and Internet-of-things applications.

Printed antennas can be utilized in communications with shorter (millimetre) ranges, even for on-chip or inter-chip applications. Miniaturized sensor systems applications can benefit from integrating printed antennas into silicon integrated circuits, but several requirements must be considered. A few millimeters or less is the required size reduction, which causes the operating frequency to rise to tens of GHz and the gain to fall. Efficiency is significantly impacted by silicon losses. Circuits surrounding the source alter the radiation pattern. When these restrictions were first discovered [5], encouraging findings were reached.

STRAIN MEASUREMENT

The frequency response of a particular antenna depends on its dimensions. Regarding patch antennas, the electrical length is inversely proportional to the antenna's resonant frequency (at a particular resonant mode). The resonance frequency of such an antenna will depend on the applied strain if it is bonded to a flexible substrate [6]. Numerous applications of this measuring technique exist in strain sensing, including non-destructive evaluation, condition-based maintenance, damage detection, structural health monitoring, and failure prevention.

RFID APPLICATIONS

In October 1948, Radio Frequency Identification (RFID) was developed in response to Harry Stockman's paper "Communications by Means of Reflected Power". The widely utilized "Identification of Friend or Foe" (IFF) system for airplanes was one of the first applications of RFID. R.F. Harrington developed the electromagnetic theory for the RFID application, and the 1960s prepared the way for the RFID boom. Commercial RFID uses first appeared in the 1960s; Electronic Article Surveillance (EAS) is one such application [7].

Integrated printed antennas with RFID technology have been integrated using flexible substrates. Systems with multipurpose blocks can be created this way, working towards the "micro lab" notion [8]. This example describes the integration process of metal-oxide gas sensors with a Spiral antenna having 5 turn-on Kapton substrate.

ENERGY HARVESTING/RECTENNA(ANTENNA+ RECTIFIER)

We should finally focus on using printed antennas as a part of the power supply block in sensor systems, as was recently reevaluated [9]. In a number of scenarios, low-power sensor systems can work by gathering ambient energy [10]. Because more and more devices are becoming wireless, ambient microwave energy is becoming a feasible source of power for these kinds of systems. For the rectifying process to be precise and efficient, radiofrequency energy must be collected using broadband antennas. They are commonly referred to as rectennas [11]

A block schematic of the rectenna used to gather free space (ambient) radio frequency energy is shown in Fig. 1. Free space RF energy is gathered using a rectenna, which consists of an antenna to collect the energy. Then a rectifier is used to convert the free space RF energy into DC power with a matching network to accept the maximum RF energy form receiving antenna and supply to rectifier circuit. An electrical gadget is powered by the energy the antenna absorbs and transforms into DC power.

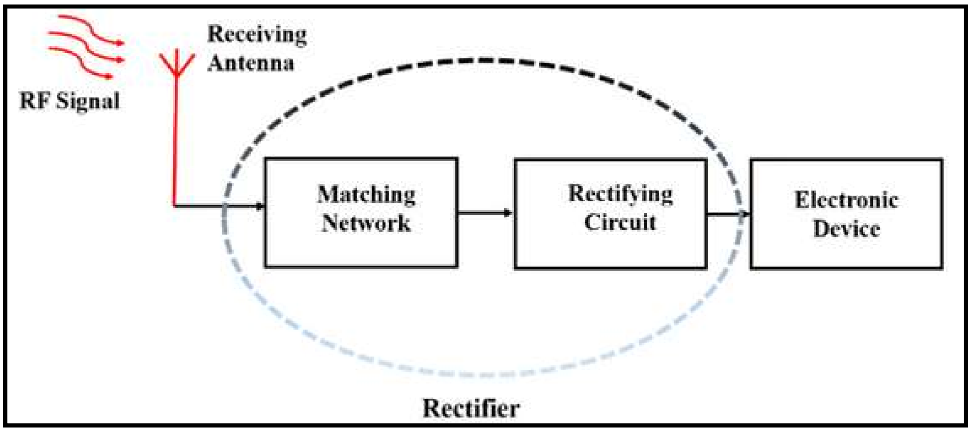

Figure 1. *Hybrid Energy System Free Space energy harvesting block diagram [12]*

REFERENCES

[1] Reig, C., & Avila-Navarro, E. (2013). Printed antennas for sensor applications: A review. IEEE Sensors Journal, 14(8), 2406-2418. powered, wireless sensors for environmental, gas, and authentication-based sensing. IEEE Sensors Journal, 11(12), 3139-3152.

[3] Hall, P. S., Hao, Y., Nechayev, Y. I., Alomainy, A., Constantinou, C. C., Parini, C., ... &Bozzetti, M. (2007). Antennas and propagation for on-body communication systems. IEEE Antennas and Propagation Magazine, 49(3), 41-58.

[4] Mahfouz, M., To, G., & Kuhn, M. (2011). No strings attached. IEEE Microwave Magazine, 12(7), S34-S48.

[5] KK, O., Kim, K., Floyd, B. A., Mehta, J. L., Yoon, H., Hung, C. M., ... & Brewer, J. E. (2005). On-chip antennas in silicon ICs and their application. IEEE Transactions on Electron Devices, 52(7), 1312-1323.

[6]Huang, H. (2013). Flexible wireless antenna sensor: A review. IEEE sensors journal, 13(10), 3865-3872.

[7] Tedjini, S., Vuong, T. P., & Beroulle, V. (2005, October). Antennas for RFID tags. In Proceedings of the 2005 joint conference on Smart objects and ambient intelligence: innovative context-aware services: usages and technologies (pp. 19-22).

[8] Abad, E., Zampolli, S., Marco, S., Scorzoni, A., Mazzolai, B., Juarros, A., ...&Sayhan, I. (2007). Flexible tag microlab development: gas sensors integration in RFID flexible tags for food logistics. Sensors and Actuators B: Chemical, 127(1), 2-7.

[9] Shrestha, S., Noh, S. K., & Choi, D. Y. (2013). Comparative study of antenna designs for RF energy harvesting. International Journal of Antennas and Propagation, 2013.

[10] Piñuela, M., Mitcheson, P. D., &Lucyszyn, S. (2013). Ambient RF energy harvesting in urban and semi-urban environments. IEEE Transactions on microwave theory and techniques, 61(7), 2715-2726.

[11] Hagerty, J. A., Helmbrecht, F. B., McCalpin, W. H., Zane, R., &Popovic, Z. B. (2004). Recycling ambient microwave energy with broadband rectenna arrays. IEEE Transactions on Microwave Theory and Techniques, 52(3), 1014-1024.

[12] Shi, Y., Jing, J., Fan, Y., Yang, L., & Wang, M. (2018). Design of a novel compact and efficient rectenna for WiFi energy harvesting. Progress in electromagnetics research C, 83, 57-70.

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POWER QUALITY-PREVALENT ISSUES AND SOLUTIONS

ABSTRACT

The rise in power electronics has affected several loads traditionally assumed to be linear. However, with time, there has been a rapid rise in non-linear loads, which is anticipated to show a dramatic increment. Consequently, this adversely affects the power quality, leading to adverse issues, some of which are discussed in this article: voltage dips, fluctuating voltage, voltage spikes, voltage swell, harmonic distortion, and short and prolonged interruptions. These prevalent power quality issues can be managed and mitigated using power conditioning devices (Filters, isolation transformers, and transient voltage surge suppressors) and energy storage systems (flywheels and superconductive magnetic energy storage).

INTRODUCTION

At present, the capacity of generating electricity is not enough to meet the rapid increase in its demand in several developing countries, such as Pakistan. Due to the existing risk of limited sources of electrical power, large number of practitioners and researchers have begun to focus on monitoring, implementation, and correction of power. This can be justified by the fact that high power transmission, generation, and distribution costs require effective controlling and monitoring of power quality [2]. Considering the utility viewpoint, power quality is defined in terms of reliability. It means voltage parameters that pose an impact on customers' supersensitive equipment. From a manufacturer's viewpoint, power quality is defined as a power that facilitates the proper working of the equipment [3]. This definition reflects that power quality reflects any current, voltage, and frequency deviation issue leading to equipment mis-operation or failure. Moreover, from the viewpoint of a power user, power quality means any electrical connection or parameter that impacts the equipment's working [4].

This article discusses the prevalent power quality issues and proposes suitable solutions to handle and mitigate them.

PREVALENT ISSUES

The rapid rise in power quality issues and the resultant financial challenges have raised concerns in the present era. As per statistical findings, 30 - 40% of business interruptions usually occur due to issues in power quality [5]. The nature of electric loads has changed due to the extensive application of electronic equipment such as information technology equipment, programmable logic controllers, adjustable speed drives, and energy-efficient lighting. These wide-ranging electric loads' widespread implementation and non-linearity are critical causes of power quality issues [6]. The most common power quality issues adversely affect sensitive equipment in terms of either premature failure or malfunctioning.

A. Fluctuating Voltage

There are several reasons for fluctuating voltage, including frequent termination or start of electric motors, arc furnaces, and oscillating loads. This results in problematic outcomes, including flickering lighting and under voltages, which reflect unsteady visual perception.

B. Voltage Dips

Voltage dip is defined as under-voltages in short duration. Usually, voltage sag decreases to 0.1 - 0.9 pu in rms current or voltage. The start of large loads or system failure leads to voltage dips. Some other causes of under voltage and voltage dips include loss of generation, malfunctions in the voltage regulator, extreme network loading, and inaccurate setting of transformer taps. Consequently, equipment maintains power output by taking additional current, which results in overloading issues.

C. Short and Long Interruptions

Very short interruption occurs when the electrical supply is interrupted for milliseconds to 2 seconds. As a result, automatic opening and reclosure of protection devices create problems in the network. This leads to adverse outcomes regarding information loss, protection devices' ripping, and faulty data processing equipment. On the contrary, a long interrupted electrical supply encompasses a time duration of 1 - 2 seconds, which halts all equipment. Its leading causes range from striking poles, human error, fire, storms, protection devices' failure, and weak coordination of devices to failure in the power system network.

D. Voltage Swell

It means an increment of 1.1 - 1.8 pu in rms current or voltage. Its most common causes include poor dimensions of power sources, termination or start of heavy loads, and poor regulation of transformers in off-peak hours. As a result, this leads to adverse consequences such as flickering of lighting, loss of data, and damaged sensitive equipment during high voltage.

E. Harmonic Distortion

Harmonic distortion results from

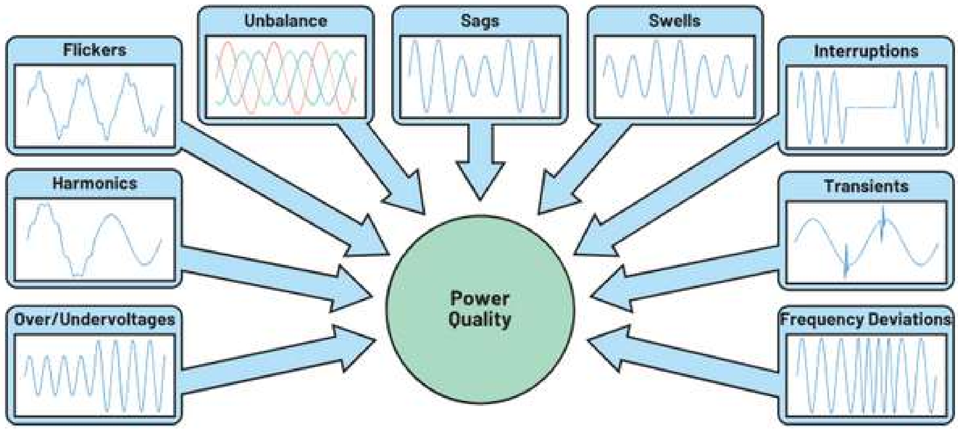

Figure 1. *Power Quality issues [7]*

working electric machines above the magnetic saturation level, welding machines, DC motor, arc furnaces, rectifiers, and various non-linear loads, including switched-mode power supplies, high-efficiency lighting, adjustable speed drives, and data processing equipment. The adverse consequences range from neutral overload in 3-phase systems, low efficiency in electric machines, measurement errors, high probability of occurrence of resonance, interference of electromagnetism with communication systems, and overheated equipment and cables.

F. Voltage Spikes

Voltage spikes include instantaneous rises in the voltage that exist for a long time. For example, above-normal voltage, such as 110% voltage, results in a voltage surge. Generally, turning off heavy electric equipment results in voltage spikes [8].

SOLUTIONS

A. Power Conditioning Devices

The power quality strategy can be enhanced by using power conditioning devices. For instance, power can be conditioned cost-effectively and most easily using a Transient Voltage Surge Suppressor (TVSS). The purpose of this unit clamp is to transient spikes to a safe level for an electronic load. Usually, TVSS is used as an interface between sensitive loads and the power source. A non-linear resistance in the TVSS confines the additional line voltage and conducts the excess impulse energy to the ground. Consequently, it clamps the transient voltage before reaching the load.

Another power conditioning device includes Filters, which exist in various forms, such as harmonic or noise filters. The purpose of noise filters is to stop unwanted voltage signals or frequency currents from reaching sensitive equipment. When inductances and capacitors are used together, a high-impedance path to a higher frequency and a low-impedance path to the fundamental frequency are created. Similarly, unwanted harmonics are minimized by using Harmonic filters. By using passive components such as capacitors, inductors, and resistors, passive filters help to attenuate harmonic frequencies in a low impedance path.

The isolation transformer is another power conditioning device that isolates mains' noise and transients from the sensitive loads. One of the most important features of isolation transformers is the presence of a non-magnetic foil-based grounded shield, which exists between the secondary and the primary. The mechanism and design goal of the isolation transformer is exhibited in Figure 2, which shows how it attenuates normal-mode and high common-mode noise. As soon as the main source produces any transient or noise, it is transmitted to the ground through the capacitance between the shield and the primary instead of reaching the load. As a result, isolation transformers assist in terms of minimizing common and normal mode noises. However, it is argued that these transformers fail to compensate for power outages or the issue of fluctuating voltage [8].

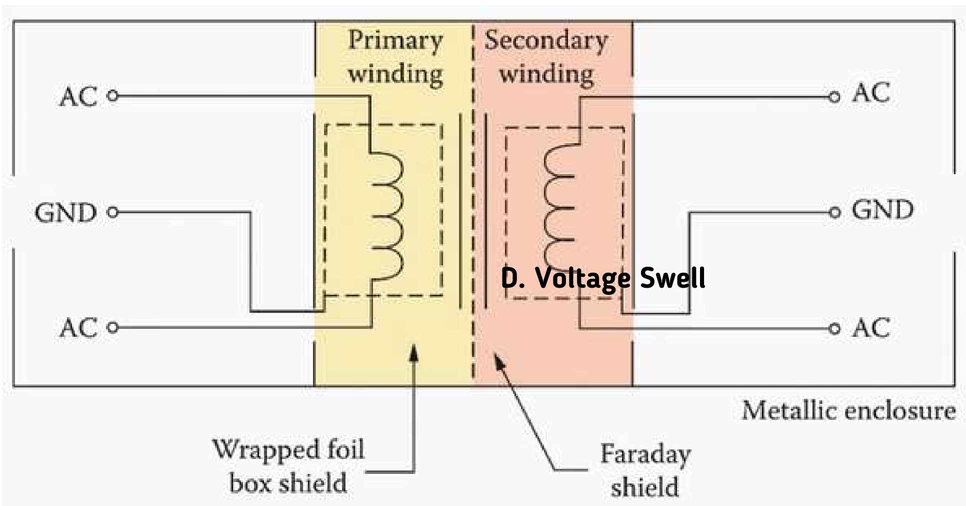

Figure 2. *Shielding arrangement within a high-performance isolation transformer [9]*

B. Energy Storage Systems

Energy storage systems such as Flywheels are crucial in improving power quality. The flywheel is an electrotechnical device that saves short-term energy by coupling a rotating mass with a rotating electric machine, such as a generator or a motor. The power sources from the grid help the motor or generator to keep spinning the flywheel rotor. Whenever the power connection is disturbed, the generator transforms the kinetic energy saved in the rotor to DC electric energy. As a result, a control system, along with an inverter, manages to deliver the energy at a constant voltage and frequency. For example, magnetic bearings and carbon fibre materials are used to construct cutting-edge flywheels, which can spin at 40,000 - 60,000 RPM in a vacuum. Typically, Flywheels offer 1 - 100 seconds of ride-through time, due to which backup generators get online within merely 5 - 20 seconds. Furthermore, it must be noted that the energy stored is directly proportional to the moment of inertia and square of rotational speed. In this regard, high-speed flywheels are better than conventional flywheels because the former have more energy storage capacity.

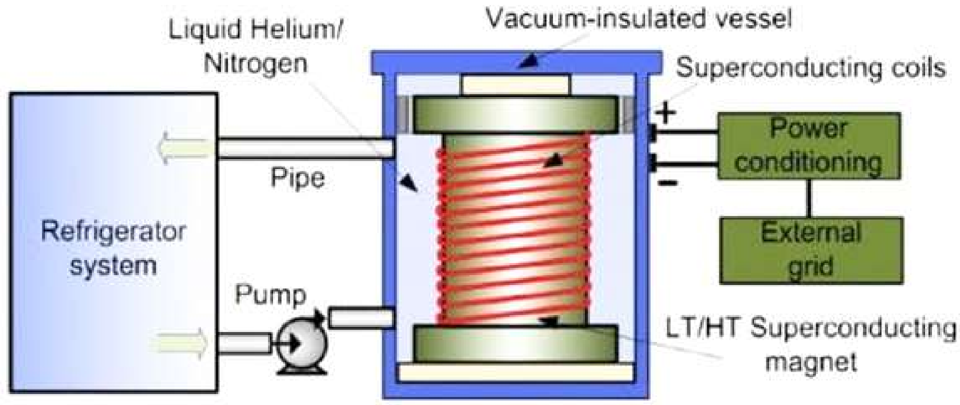

Figure 3. *Working Principle of Super Conducting Magnetic Energy Storage (SMES) [10]*

Another example of an energy storage system is superconductive magnetic energy storage, also abbreviated as SMES. When a DC circulates in the superconducting wired closed coil, this creates a magnetic field. Using a solid-state switch facilitates the opening of the path of the coil circulating current. Whenever the switch is open (off) due to the high inductance of the coil, the magnetic coil works as the current source. The current is forced into a power converter that is charged to a certain voltage level.

Meanwhile, proper modulation of the solid-state switch plays an important role by holding the voltage within the inverter's suitable operating range. This leads to the conversion of the DC voltage into AC power. Low-temperature SMES are widely available in the market and are cooled by liquid helium (figure 3). On the contrary, less expensive high-temperature SMEs still need to be fully developed. However, they are anticipated to be a practical commercial energy storage source in the near future [8].

CONCLUSION

In the current era of development, Pakistan's energy sector needs to focus on power quality issues and their management in key industry areas, specifically the power sector. The concept of power quality has gained widespread focus amidst the present-time usage of sophisticated electrical equipment. The extensive application of such cutting-edge equipment has complicated the electrical power aspects and posed adverse impacts due to their high sensitivity to the effects of power quality. This article has highlighted several power quality issues that result in corrupted data, lack of power efficiency, lower productivity, data loss, and equipment failure. However, the identified power quality issues are proposed to be managed and mitigated using power conditioning devices and energy storage systems

REFERENCES

[1] Power Quality Analysis - Janitza electronics. (n.d.). Retrieved from https://www.janitza.com/us/power-quality-analysis.html

[2] Naderi, Y., Hosseini, S. H., Zadeh, S. G., Mohammadi-Ivatloo, B., Vasquez, J. C., & Guerrero, J. M. (2018). An overview of power quality enhancement techniques applied to distributed generation in electrical distribution networks. Renewable and Sustainable Energy Reviews, 93, 201-214.

[3] Khalid, S., & Dwivedi, B. (2010). Power quality: An important aspect. Int. J. Eng. Sci. Technol, 2(11), 6485-6490.

[4] Ignatova, V., Lafort, M., & Billic, I. (2015, June). Power quality management methodology. In International Conference on Electricity Distribution.

[5] Mamonova, A. O., Khusnutdinova, E. M., & Khusnutdinov, A. N. (2020, September). Quality management when operating the power equipment. In IOP Conference Series: Materials Science and Engineering (Vol. 915, No. 1, p. 012039). IOP Publishing.

[6] NAGARAJU, K., & BABU, B. R. Simulation of Power Quality Issues of Wind power integrated systems and results analysis.

[7] Mendia, J. (2023, January 16). Power Quality Monitoring Part 1: The Importance of Standards Compliant Power Quality Measurements. Retrieved from https://www.analog.com/en/analog-dialogue/articles/power-quality-monitoring-part-1-the-importance-of-compliant-power-quality-measurements.html

[8] Kumar, P. (2017). A Review of Power Quality Problems, Standards and Solutions. International Research Journal of Engineering and Technology (IRJET), 4(01).

[9] Csanyi, E. (2021, July 21). The magic that isolation transformer uses to suppress transients and noise. Retrieved from https://electrical-engineering-portal.com/isolation-transformer-suppress-transients-noise#:~:text=The%20windings%20are%20separated%20physically,from%20secondary%20to%20the%20primary.

[10] Imandi, R. (2021, December 28). Superconducting Magnetic Energy Storage Systems (SMES). Retrieved from https://rohitimandi.medium.com/superconducting-magnetic-energy-storage-systems-smes-4a9c16a4727d

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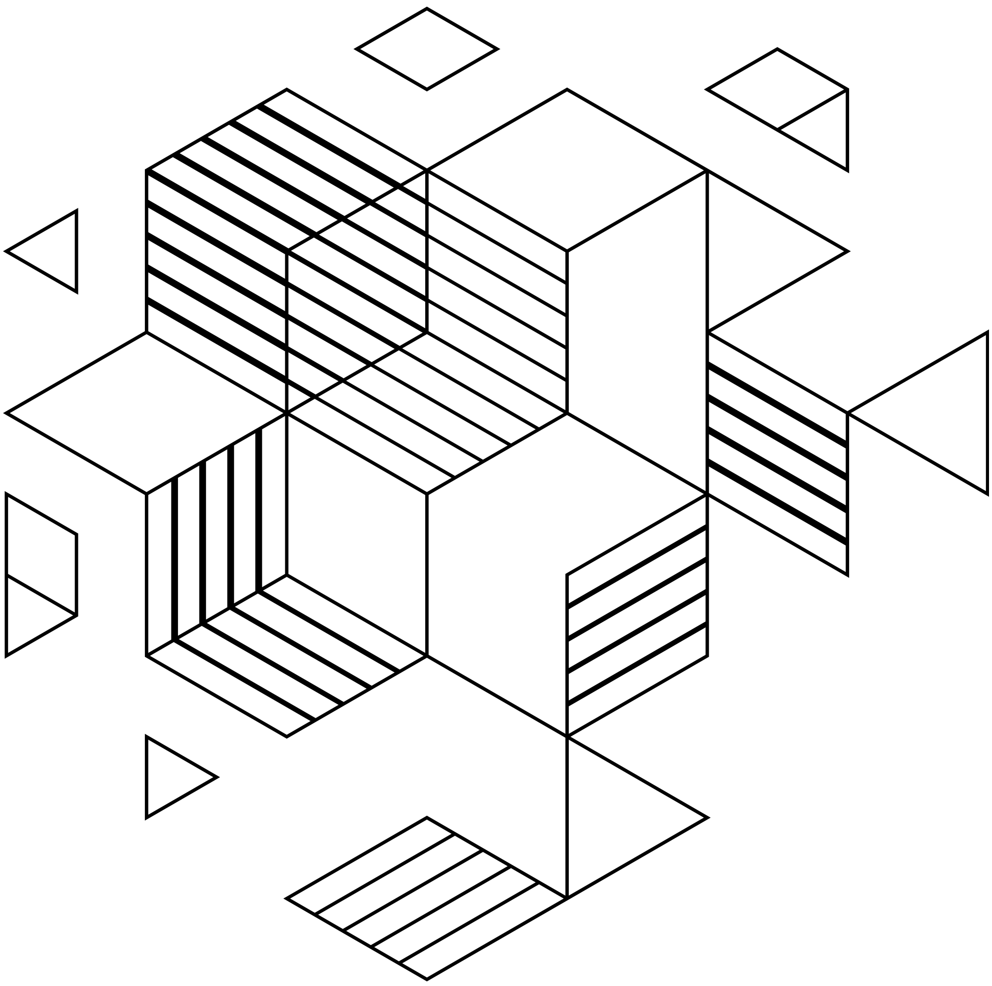
بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

وَيَسْتَعْجِلُونَكَ بِالسَّيِّئَةِ قَبْلَ الْحَسَنَةِ وَقَدْ خَلَتْ مِنْ قَبْلِهِمُ
الْمَثُلَاتُ ۗ وَإِنَّ رَبَّكَ لَذُو مَغْفِرَةٍ لِلنَّاسِ عَلَىٰ ظُلْمِهِمْ ۖ وَإِنَّ
رَبَّكَ لَشَدِيدُ الْعِقَابِ ﴿٦﴾ وَيَقُولُ الَّذِينَ كَفَرُوا لَوْلَا أُنْزِلَ
عَلَيْهِ آيَةٌ مِنْ رَبِّهِ ۗ إِنَّمَا أَنْتَ مُنْذِرٌ ۖ وَلِكُلِّ قَوْمٍ هَادٍ ﴿٧﴾

They ask you ˹O Prophet˺ to hasten the torment rather than grace, though there have ˹already˺ been ˹many˺ torments before them. Surely your Lord is full of forgiveness for people, despite their wrongdoing, and your Lord is truly severe in punishment. The disbelievers say, "If only a sign could be sent down to him from his Lord." You ˹O Prophet˺ are only a warner. And every people had a guide.

QS (Ar-Ra'd:6-7)



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