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Automatic Load Sharing of Transformer: A Comprehensive Review

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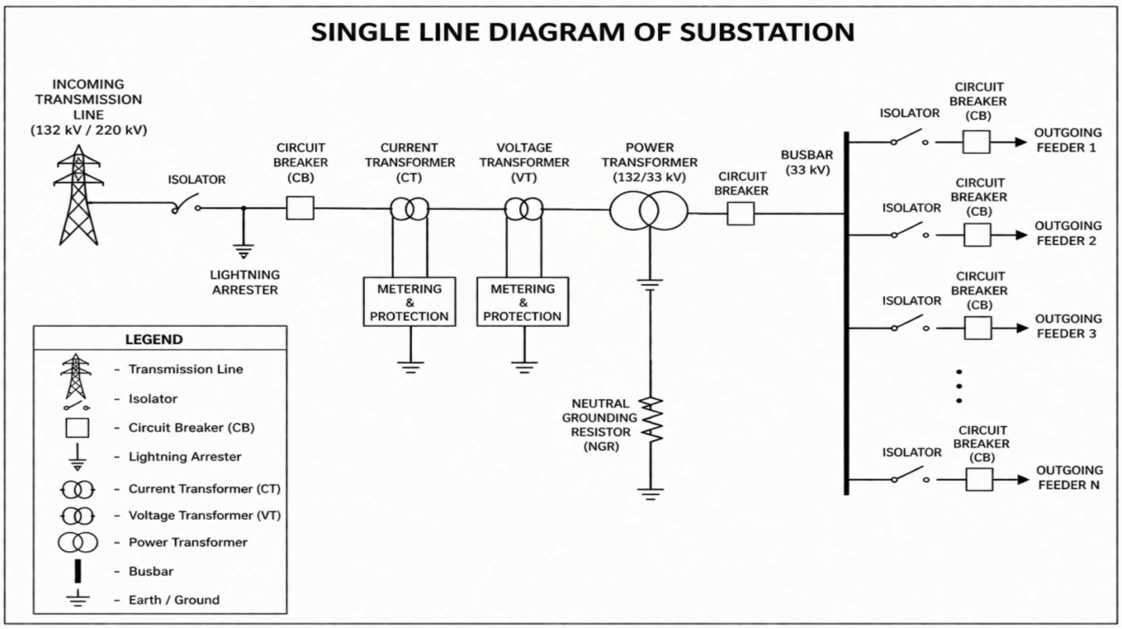
Abstract: Modern electrical power systems require efficient and reliable energy distribution to meet the growing demands of complex electrical grids. Transformers play a vital role in transmission and distribution networks; however, the limitations of single transformer operation and overloading issues necessitate advanced load management techniques. To address these challenges, this paper focuses on automatic load sharing methods based on the parallel operation of transformers. The proposed approach enables balanced load distribution among multiple transformers, thereby enhancing system efficiency, reducing power losses, and improving overall reliability. Additionally, the system ensures proper coordination by considering critical parameters such as voltage ratio, impedance matching, and phase sequence. The load sharing mechanism also supports uninterrupted power supply during fault or maintenance conditions by redistributing the load among available units. Furthermore, monitoring and protection strategies are incorporated to maintain stable operation under varying load conditions. The performance of the system is analyzed under different operating scenarios, demonstrating improved voltage regulation, operational stability, and effective utilization of transformer capacity.

I. INTRODUCTION

Transformers is one of the most significant equipment in the electrical power system, hence transformer required protection. Apart from this the demand for electricity is increasing due to the increasing population and their unavoidable demands, with this increased power requirement, the existing systems have become overloaded. The overloading appears at the consumer end of the transformer terminals, which can affect its efficiency and protection systems. Due to overload on the transformer the efficiency drops and the windings gets over heated and may get burnt. It takes a lot of time to repair and lot of expenditure. Transformers are occasionally loaded beyond nameplate ratings because of existing possible contingencies on the transmission lines, any failure or fault in power systems, or economic considerations. One of the reported damage or tripping of the distribution transformer is due to thermal overload. To eliminate the damaging of transformers due to overloading from consumer end, it involves the control against over current tripping of distribution transformer. Rise in operating temperature of the transformer. The project is all about protecting the transformer under overload condition. by connecting another transformer in parallel through a microcontroller and a relay which shares the excess load of the first transformer. The transformers are switched alternatively to avoid thermal overloading. Therefore, two transformers work efficiently under overload condition and damage can be prevented. If there is a further increase in load beyond the capacity of two transformers there will be a priority-based load shedding of consumers which will provide uninterrupted power supply for the hospitals, industries etc. Transformers play a pivotal role in electrical distribution systems, facilitating power transmission over long distances and stepping down voltage for safe consumption. As the demand for electrical energy grows in today's technological landscape, transformers become even more essential, grappling with challenges like varying loads and disruptions. The uneven distribution of loads on transformers within modern grids poses a significant challenge. Manual load-sharing methods are inadequate for the complexities of today's grids, leading to inefficiency and equipment risks. Automatic load sharing of transformer hardware emerges as a solution, utilizing advanced technologies like microcontrollers and adaptive algorithms to optimize energy distribution, enhance reliability, and extend infrastructure lifespan. This comprehensive review delves into automatic load sharing of transformer hardware, exploring transformer types, load-sharing principles, historical limitations, and recent advances. The paper addresses challenges, cybersecurity considerations, and real-world case studies, aiming to be a valuable resource for researchers and decision-makers in the field. The significance of transformers in electrical distribution is undeniable, and the need for automatic load sharing is more critical than ever. This review provides insights into the past, present, and future of this technology, offering guidance for ensuring the reliability and efficiency of electrical power distribution systems.

II. LITERATURE SURVEY

Develop an efficient and reliable approach for substation analysis, which involves representing power flow and system components using a simplified single line diagram (SLD). The proposed model focuses on visualizing electrical power distribution from incoming transmission lines to outgoing feeders through key substation elements such as circuit breakers, isolators, transformers, and busbars. The SLD-based approach enables clear understanding of system configuration, operational control, and protection mechanisms within the substation. The methodology utilizes structured representation techniques to illustrate the interconnection of components and the flow of electrical energy across different voltage levels. The system highlights the role of switching and protection devices in ensuring safe and continuous operation under varying load conditions. The proposed model effectively demonstrates power flow management, fault isolation, and load distribution within the substation. The results indicate that the SLD-based representation is a practical and efficient method for analyzing substation operation, improving system reliability, and supporting planning and maintenance activities in power distribution networks. [1]



The substation system operates based on monitoring and control using a single line diagram (SLD). During normal conditions, power flows from the transmission line through components such as isolators, circuit breakers, and transformers for proper distribution. The protection system continuously monitors parameters and detects faults or overloads. In such situations, circuit breakers isolate the faulty section, while isolators ensure safe maintenance. The busbar distributes power to multiple feeders, maintaining system continuity. The system also supports rerouting of power to ensure uninterrupted supply. This approach provides effective fault isolation, improved stability, and efficient load distribution within the substation.

The proposed substation system effectively addresses the issue of load imbalance and power distribution inefficiencies by utilizing a structured single line diagram (SLD) representation. The system ensures proper load distribution among multiple feeders through coordinated operation of transformers, busbars, and switching devices, thereby enhancing overall performance and efficiency of the distribution network. The real-time monitoring and protection mechanisms improve the adaptability and responsiveness of the system under varying load conditions. The primary challenge considered is the imbalance in load distribution across different feeders due to uneven demand in the network. To overcome this, the system continuously monitors load conditions and manages power flow through appropriate switching and control actions. The proposed approach enables automatic routing of power to less loaded feeders, ensuring balanced operation. As a result, the system improves reliability, maintains voltage stability, and ensures efficient utilization of substation capacity under dynamic operating conditions. [2]

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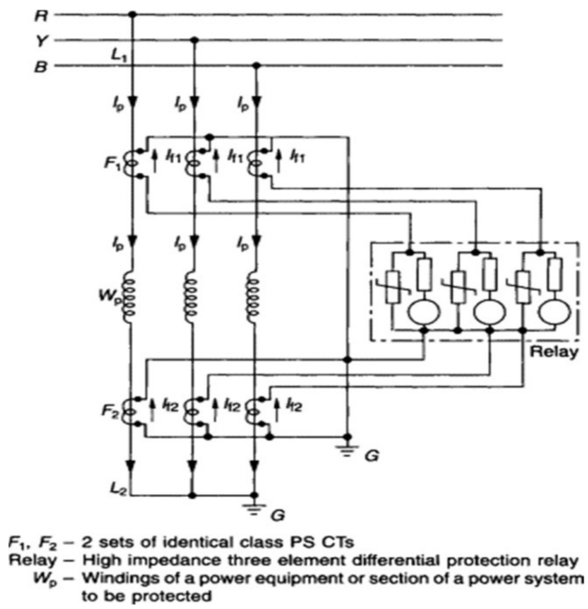
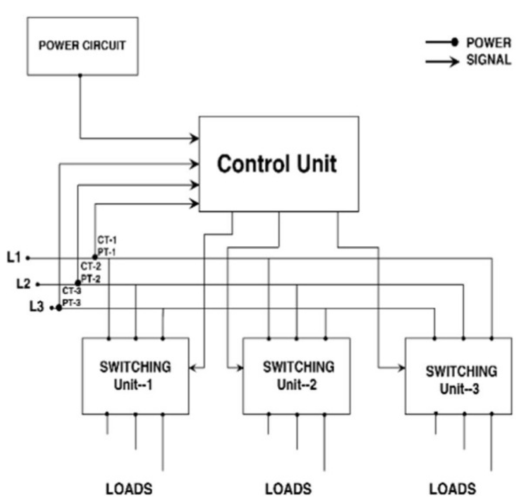


The development of an automated load management system at the domestic level to address issues related to load unbalancing and excessive energy consumption. The system incorporates current and potential sensing transformers, an Arduino Mega board, and utilizes the Internet of Things (IoT) for remote monitoring. To domestic load management by utilizing sensing transformers, an Arduino Mega board, and IoT technology. The integration of real-time monitoring and load shifting capabilities empowers users to make informed decisions and optimize their energy consumption. Both simulation and hardware results validate the effectiveness of the proposed system in achieving its objectives.

The control unit consists of Arduino mega 2560 microcontroller that analyzes the load and power on each incoming line. Moreover, the controller also measures the current consumption of the load with the help of CTs and PTs. The Arduino tries to balance the load on each line by sending switching signals to the relay unit, which will shift the load on different lines. According to the algorithm, the load on each line will be calculated separately and if the load increases than the threshold value then the controller finds the less loaded line. On finding the less loaded line, the controller shifts the high power consuming electrical appliances to that line. It is pertinent to state here that all the lines are not perfectly balanced.



The implementation of a microcontroller fault detection and monitoring system for power transformers. The system utilizes various sensors and devices, such as Arduino microcontrollers, voltage transformers and current transformers to enhance the reliability and safety of power transformers. The microconroller-based fault detection and monitoring system described in the passage contributes to the efficient and safe operation of power transformers.

It combines fault detection, real-time parameter monitoring, and control capabilities to address issues promptly and enhance the overall reliability of the power distribution network. The utilization of microcontroller allows for remote monitoring, enabling timely decision-making and maintenance interventions.

III. PROPOSED SYSTEM DEVELOPMENT

2.2 Block Diagram

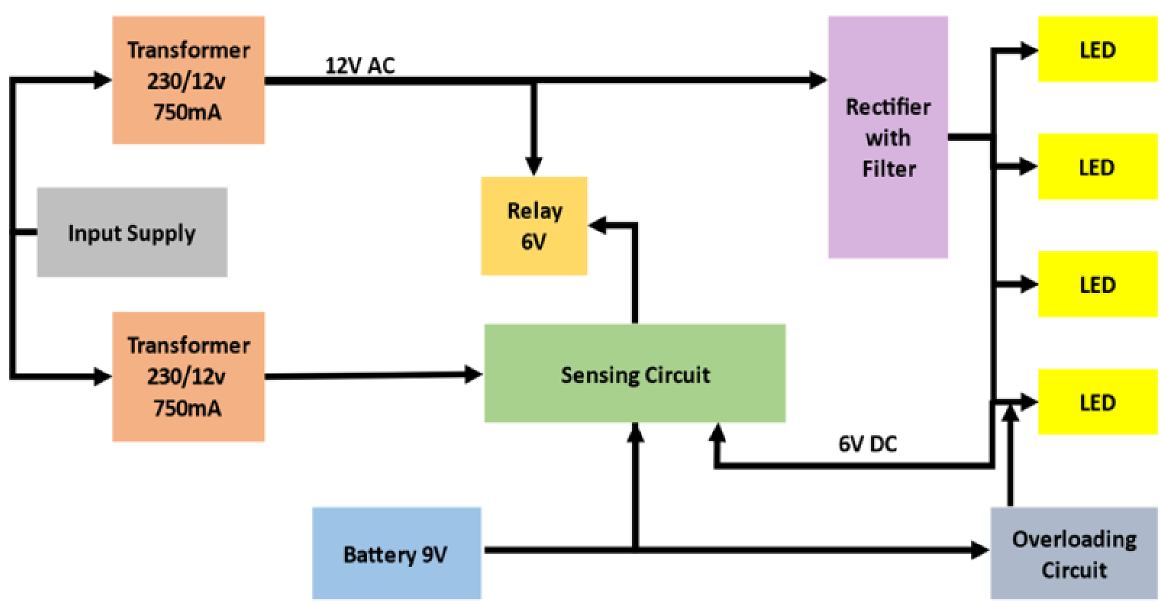


Figure 1 Block Diagram

B. Comparison Table

In this table, we explore various approaches and technologies applied to the domain of electrical systems and load management. The following table presents a comparative analysis of different studies.

Literature Survey Topic	Methodology	Key Technologies	Conclusion
Electricity: Efficient Transformer for NILM	Non-Intrusive Load Monitoring (NILM)	Machine Learning, Signal Processing	Efficient NILM system using machine learning for load monitoring. High accuracy in identifying individual appliance consumption. Enables energy disaggregation without the need for intrusive sensors.
Smart Load Balancing in 3-phase 4-wire System	Dynamic Load Balancing	3-phase 4-wire distribution system	Effective load balancing in 3-phase 4-wire systems for optimal energy distribution. Minimizes phase imbalances and reduces losses. Utilizes real-time monitoring and control to enhance the efficiency of the distribution network.

Dynamic Load Sharing at Domestic Level using IoT	Dynamic Load Management.	Smart Appliances, Sensors.	Optimal load distribution in a household using controller. Utilizes real-time data from sensors and smart appliances for dynamic load management. Improves energy efficiency, reduces costs, and provides user-friendly interfaces.
Load Sharing of Transformers by Arduino with GSM	Load Sharing Control, Arduino, GSM	Transformers, Relays, Current Transformers (CTs)	Automation of load sharing among transformers using Arduino and GSM modules. Provides a costeffective solution for preventing overloads and optimizing transformer utilization in power distribution systems.
IoT-based Distribution Transformer Monitoring System	Distribution Transformer Monitoring, IoT	IoT Devices, Cloud Computing, Communication Protocols	Real-time monitoring and protection of distribution transformers using IoT. Enhances transformer operational status monitoring, reduces downtime, and improves the overall reliability and efficiency of power distribution networks.

LOAD SHARING DATA OF SUB-STATION :-
Guru GhasidasViswavidyalaya,bilaspur:-
Summer :-

Time (Am)	Birkona	GGU	Sendri	GEC BSP	Main-1	Main-2
6:00	30A	118A	12A	24A	148A	13A
7:00	28A	101A	12A	24A	127A	12A
8:00	26A	100A	10A	22A	126A	12A
9:00	26A	95A	10A	22A	120A	11A
10:00	24A	90A	9A	20A	114A	10A
12:00	22A	88A	7A	20A	104A	9A

Time (Pm)	Birkona	GGU	Sendri	GEC BSP	Main-1	Main-2
7:00	37A	126A	10A	17A	164A	8A
8:00	38A	125A	11A	20A	162A	8A
9:00	44A	120A	11A	24A	158A	11A
10:00	48A	122A	10A	25A	166A	11A
11:00	30A	115A	9A	26A	174A	12A
12:00	32A	115A	14A	26A	174A	13A

Winter :-

Time (Am)	Birkona	GGU	Sendri	GEC BSP	Main-1	Main-2
7:00	39A	75A	7A	19A	136A	28A
8:00	39A	102A	9A	22A	159A	32A
9:00	35A	120A	10A	21A	162A	30A
10:00	33A	123A	9A	26A	144A	26A
12:00	26A	96A	7A	19A	106A	25A

Time(Pm)	Birkona	GGU	Sendri	GEC BSP	Main-1	Main-2
8:00	22A	85A	9A	22A	107A	31A
9:00	24A	88A	9A	24A	112A	33A

10:00	24A	90A	9A	24A	114A	33A
11:00	25A	95A	9A	24A	120A	33A
12:00	26A	98A	9A	24A	124A	33A

Average value of load according to sub-station :-

Guru GhasidasViswavidyalaya,bilaspur (Summer) :-

Area	Day	Night
Main-1	123.16A	166.33A
Main-2	11.16A	10.16A
Birkona	26A	38.16A
GGU	98.66A	101.33A
Sendri	10A	12.16A
GEC BSP	22A	23A

Graph:-

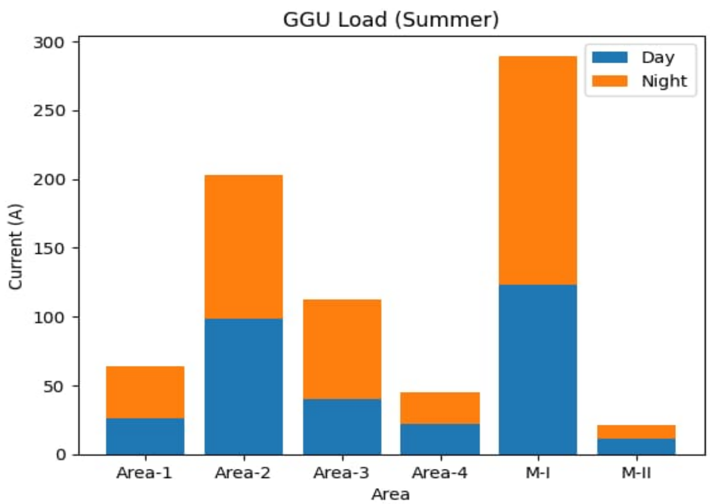
- TheMain-1 area carries the highest load, with 123.16 A during the day and 166.33 A at night, indicating peak demand in this region.
- TheGGU area also shows significantly high load values, contributing majorly to the total system load.
- Moderate loads are observed in Birkona and GEC BSP, showing balanced consumption.
- Thelowest load is recorded in Sendri and Main-2, indicating comparatively lesser demand in these areas.
- In most areas, the **night load is higher than the day load**, which suggests increased electricity usage during evening and night hours in summer (possibly due to cooling appliances like fans, coolers, and ACs).

formula

$$\text{Average Load} = \frac{\text{Total Load of all areas}}{\text{Number of areas}}$$

Purpose

- To understand how evenly the load is distributed
- To prevent overloading of any feeder
- To improve system efficiency and reliability



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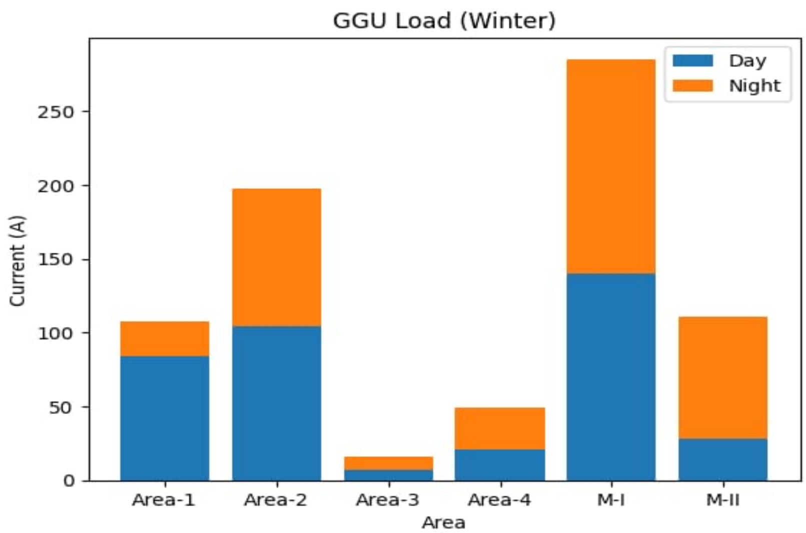
Winter :-

Area	Day	Night
Main-1	146A	24.2A
Main-2	28.16A	32.6A
Area-1 Birkona	33.3A	24.2A
Area-2 GGU	104.16A	93.2A
Area-3 Sendri	8.33A	9A
Area-4 GEC BSP	20.83A	23A

Graph:-

- TheGGU area carries the highest load, with 104.16 A during the day and 93.2 A at night, making it the major load center.
- TheMain-1 area also shows relatively high load during the day (146 A) but significantly decreases at night (24.2 A).
- Moderate load is observed in Main-2 and Birkona, indicating balanced consumption.
- Thelowest load is recorded in Sendri, showing minimal demand in both day and night.
- Unlike summer, in winter, the **day load is generally higher than the night load**, indicating reduced nighttime electricity usage due to lesser need for cooling appliances.



IV. CONCLUSION

1) In modern power systems, efficient and reliable distribution of electrical energy is very important.
2) As electrical grids are becoming more complex, it is necessary to ensure proper and optimized energy distribution.
3) Automatic load sharing plays a key role in managing power effectively across the system.
4) It helps in distributing load among multiple transformers, preventing overload on a single unit.
5) This results in improved system reliability and efficiency.
6) Proper load sharing also reduces losses and increases the lifespan of equipment.
7) Researchers are developing advanced and intelligent techniques to enhance power system performance.
8) IoT (Internet of Things) integration is improving monitoring and control of transformers.
9) IoT helps in real-time data collection and remote monitoring of electrical systems.
10) It enables early fault detection, reducing chances of major failures.
11) Overall, these technologies ensure safe, efficient, and smooth operation of power systems.

In this reading there is one common area is present in this called birkona and the load is generally supplied from the GGU sub station and some time it will supplied from sendri sub-station.

A some amphere is supplied from sendri 25A approx. to birkona during summer in peak hour.

GGU sub-station there is main-1 and main-2 is sharing transformer the load of area depend upon the line loss which in the continuous varaitions then the main-1 work on there peak load without any diversion in the system

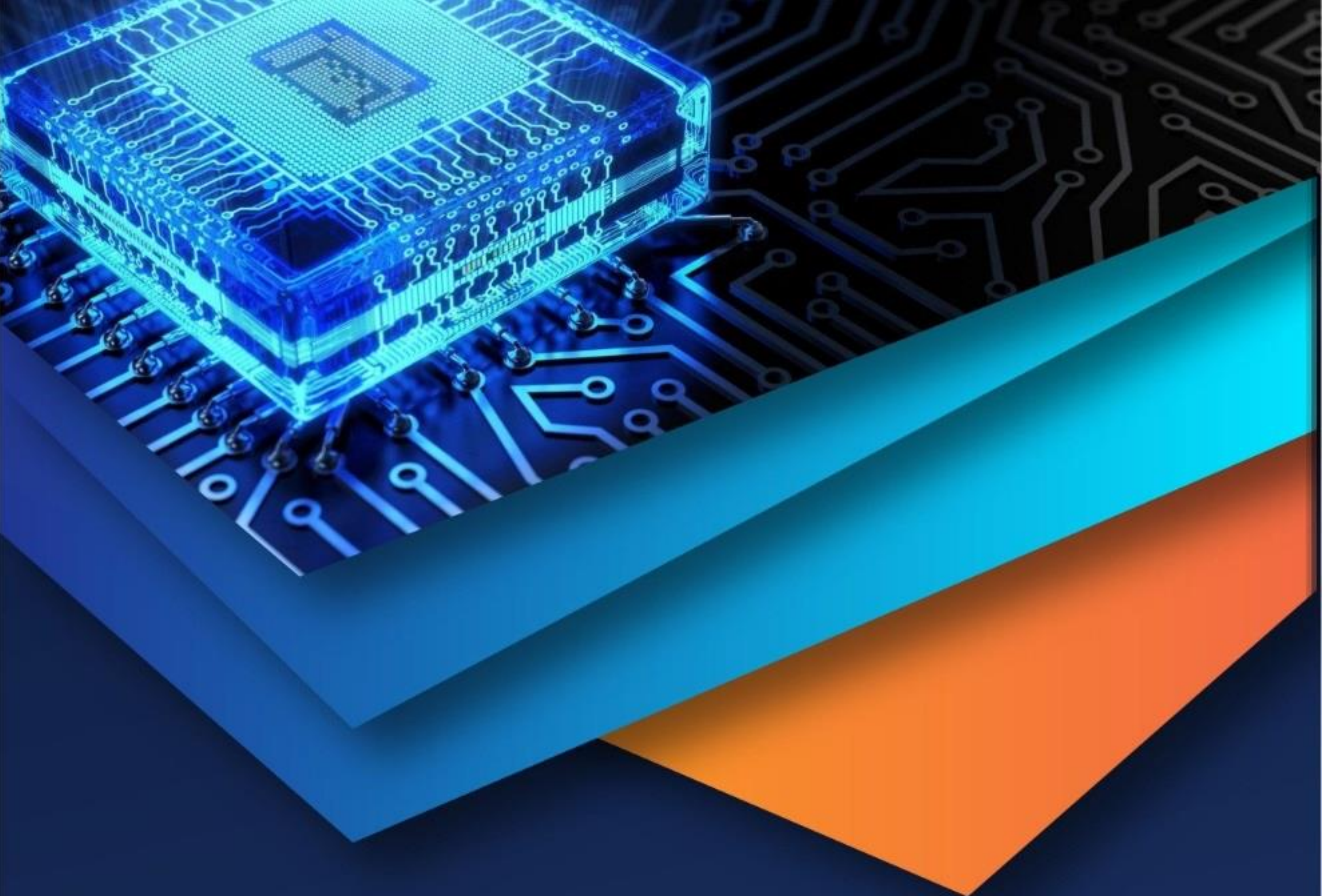
Peak Load Areas
- Main-1 and GGU are the major load-carrying areas in both seasons.
- These areas consistently contribute the highest load to the substation.

Low Load Areas
- Sendri and Main-2 show comparatively lower load in both summer and winter.
- These areas have less contribution to total load demand.

Seasonal Variation
- The load demand is higher in summer compared to winter due to the use of cooling appliances like fans, coolers, and air conditioners.

Feeder-Specific Observations
- Birkona feeder shows moderate variation.
- Sendri feeder carries the least load, indicating low demand area.
- GEC BSP feeder shows stable but medium load values.

Overall Conclusion
The substation experiences seasonal and time-based load variations, and efficient load sharing is necessary for reliable operation.



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