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# A Review on Switchgear Analysis and Common Challenges Observed in Switchgear

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*Abstract*— **The digitization of manufactured goods has now become a phenomenon with the implementation of new sensor technology and the growth of IoT instruments. People with large, exorbitant machinery would like to keep a record of the assets' critical parameters. As a result, medium voltage equipment, mainly switchgear diagnostics has become incredibly valuable. On-site analyses and monitoring of circuit breaker drives, contacts, gas quality, gas density, and partial discharges could be achieved with varying degrees of tolerance and operational efficiency. They are mounted in substations to supply energy to cities from electrical networks from overhead power lines or underground cables. Safety and efficiency are major concerns in this equipment due to the high voltage and current flow. Thus, various types of sensors are used in the system to keep track of the system's performance. This paper presents a detailed examination of the Switchgear Study, its implementations, and the challenges observed.**

***Keywords***— ***Medium Voltage Switchgears, Gas Insulated Switchgear, IoT, Safety methods, Operational Efficiency, System Performance.***

## I. INTRODUCTION

Switchgears predate the invention of electricity. The first versions were very basic, with all elements directly attached to a wall. They were then installed on wood frames. The wood was substituted with slate or marble for fire safety purposes. Since the switching and measurement instruments could be connected to the front while the wire was on the rear, this resulted in further modifications. The simplest type of switchgear is a tumbler switch with an ordinary fuse, which was used to operate and secure lights and other appliances in houses, workplaces, and other places. A high-rupturing capacity (H.R.C.) fuse and a switch can be used to control and secure higher-rated circuits. Moreover, on a high-voltage grid, though, such switchgear is unprofitable. Switchgear is made up of electrical disconnect switches, fuses, and circuit breakers that are used to operate, secure, and separate electrical devices in an electric power system. Switchgear is used to de-energize machinery so that it can perform maintenance operations on it, as well as to clear faults downstream[1]. The efficiency of the power supply is directly associated with this type of equipment. Arc energy can be stored and securely handled with oil-filled switchgear. By the early twentieth century, it was almost clear that a switchgear line-up would be a metal-enclosed structure with electrically operated switching components and oil circuit breakers. Today, air-blast, vacuum or SF6 equipment has effectively replaced oil-filled equipment today, allowing broad currents and input voltages to be safely controlled by automatic equipment. There are two categories of components in a switchgear assembly: control components that conduct or disrupt the stream of electrical power, such as switches, circuit breakers, fuses, and lightning, control systems for monitoring, controlling, and safeguarding of power driving elements, such as control panels, current transformers, future transformers, protection relays, and related circuits. Security, which is the disruption of short-circuiting and overload fault currents while sustaining operation to unaffected circuits Gts, is one of the most basic features of switchgear. Alienation of circuits from power supplies is also provided by switchgear. Switchgear can also improve system availability by allowing several sources to feed a load. Gas-insulated switchgear saves space compared with air-insulated equipment, although the equipment cost is higher. An effective although more costly form of switchgear is the gas-insulated As compared to air-insulated switchgear, gas-insulated switchgear takes up less room, but the cost of the equipment is higher, pressurized sulfur hexafluoride gas(SF6) is used to insulate conductors and contacts in switchgear (GIS)[2]. The switchgear enclosure's mix of devices allows them to interrupt fault currents of thousands of volts. The primary component that interrupts fault currents is a circuit breaker (located inside a switchgear enclosure). When the circuit breaker breaks apart the contacts (disconnects the circuit), the arc must be quenched with caution. Gas (SF6) circuit breakers use a magnetic field to extend the arc and then concentrate on the SF6 gas's dielectric power to quench the extended arc. Since there is little to ionize other than the contact medium in circuit breakers with vacuum interrupters, the arc quenches as it is extended by a tiny distance (about 2–8 mm)[3]. The arc isn't hot enough to hold a plasma at zero current, so the current stops; the void will then tolerate the voltage spike. Current medium-voltage switchgear up to 40,500 volts commonly uses vacuum circuit breakers. Since there is no "current zero" time for DC, vacuum circuit breakers are unsuitable for breaking high DC voltages. The plasma arc can be fed on its own by starting to gasify the contact material[4]. Today, the Medium voltage GIS mostly uses SF6, due to their efficient isolation and thermal properties, as the insulation and the break-down medium. While SF6 has excellent properties, it also represents the world's most dangerous greenhouse gas. Each year, only SF6 pollution led to a huge 0.5% of global warming. Due to the extreme greenhouse effects of SF6, an alternative approach to SF6 in switchgear is required.[5]

## II. TYPES OF SWITCHGEAR

The switchgear is available in three different types: LV (Low Voltage), MV (Medium Voltage), and HV (High Voltage).

### *A. Low Voltage Switchgear*

Low voltage switchgear refers to a power grid that operates at less than 1 kV. The secondary (low-tension) side of the power distribution transformer also features low-voltage switchgear. This arrangement of transformer and switchgear is called a substation. Low-voltage switchgear is normally used for the feeding of LV-MCCs and low-voltage switchboards and other branch and feeding systems. It supplies electricity to critical energy and process applications, such as heavy industry, construction, mines and steel, petrochemical, pulp and paper, water, datacenter, and healthcare. The most common equipment includes switches, LV circuit breakers, HRC fuses, earth leakage (EL), disrupting circuit breakers, offloading electrical insulators, MCBs, and MCCBs.[6]

### *B. Medium Voltage Switchgear*

Medium voltage switchgear is a switchgear device that can handle voltages ranging from 3 to 36 kV. These are available in a variety of styles, including metal-enclosed outdoor type, metal-enclosed indoor type, and outdoor type without metal enclosure. Vacuum, SF, and oil can all be used as disturbance mediums in this form of switchgear. The primary function of this form of the power network is to interrupt current flow in the event of a failure in the grid. This is capable of ON/OFF service, short circuit current interference, capacitive current switching, inductive current switching, and is used in a variety of applications. Arc furnaces, medium-voltage electrical transmission lines, SF6 gas-insulated, air magnetic, gas-insulated, vacuum and electrical power generating stations are examples of applications [7].

### *C. High Voltage Switchgear*

High voltage switchgear is a power system that deals with voltages greater than 36 kV. The arcing created during switching operation is also very high due to the high voltage level. As a result, extra caution should be exercised when building high-voltage switchgear. Since the high voltage circuit breaker (CB) is the most important part of HV switchgear, it must have specific features for safe and stable operation. High-voltage circuits with faulty tripping and switching operations are very unlikely. caused due to the friction in dielectric contact inside the circuit breaker which may lead to the destruction of the entire system or workplace in the worst scenario, this light or sparks at the initial stage will be sensed by the light sensor and this will switch on an alarm informing the controller about the malfunction occurring, thus avoiding any damage to the system. In case of any emergency, the system can then be completely turned down thus helping the industry keep a better and constant check[8].

## III. CIRCUIT BREAKER

The primary aspect that interrupts fault currents is a circuit breaker (within a switchgear enclosure). The quenching of the arc as the circuit breaker takes apart the contacts (disconnects the circuit) necessitates cautious construction. As current reaches a predetermined safe amount, circuit breakers and fuses trip. Other critical defects, such as unbalanced currents—for example, where a transformer winding touches the ground—are not detectable. Circuit breakers and fuses, on their own, are unable to differentiate between short circuits and elevated levels of electrical demands[9].

## IV. TYPES OF CIRCUIT BREAKER

Circuit breakers/insulated Switchgears fall into these five types: Oil circuit breaker, Air brake circuit breaker, Air blast circuit breaker, GIS / Sulfur hexafluoride circuit breaker, Hybrid circuit breaker, Vacuum circuit breaker.

### *A. Oil Insulted Circuit Breaker*

To blast a jet of oil down the direction of the arc, oil circuit breakers depend on the vaporization of some of the oil. Arcing causes hydrogen gas to be emitted as a vapor. Mineral oil is a more effective insulator than air. As current carrying contacts in the oil separate, the arc in the circuit breaker is initiated at the time of contact separation, and the oil is vaporized and decomposed into largely hydrogen gas, thereby forming a hydrogen bubble around the electric arc. Since the current crosses zero crossings of the cycle, this intensely dense gas bubble around the arc stops the arc from re-striking.[10]

### *B. Air Insulted Circuit Breaker*

Air Insulated Circuit Breaker (ACB) is an electrical device used to provide Overcurrent and short-circuit protection for electric circuits over 800 Amps to 10K Amps. To extend the arc, air circuit breakers may use compressed air (puff) or the magnetic power of the arc itself. The elongated arc would ultimately exhaust itself because the duration of the sustainable arc is determined by the available voltage. Alternatively, the contacts are quickly swung into a shallow enclosed chamber, blowing out the arc as the expelled air escapes[10].

### *C. Gas Insulated / SF6 Circuit Breaker*

The gas-insulated switchgear (GIS) is a popular electrical equipment that uses sulfur hexafluoride (SF6) as an insulator. It is an efficient but more expensive type of switchgear. Pressurized SF6 is used to insulate the conductors and contacts. The GIS switchgear enclosure's mix of devices allows them to interrupt fault currents of thousands of amps. When using a magnetic field to extend the arc, gas-insulated circuit breakers depend on the dielectric power of the SF6 gas to quench the extended arc[10].

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### D. *Hybrid Circuit Breaker*

The elements of a conventional air-insulated switchgear (AIS) and SF6 gas-insulated switchgear (GIS) technologies are combined in hybrid switchgear. It has a lightweight and modular architecture that combines many separate functions into a single module[10].

### E. *Vacuum Insulated Circuit Breaker*

Since there is little to ionize other than the contact medium in circuit breakers with vacuum interrupters, the arc quenches as it is extended by a tiny distance (about 2–8 mm). The arc isn't hot enough to hold a plasma at zero current, so current bridges the gap, and can then endure the voltage spike. Current medium-voltage switchgear up to 40,500 volts commonly uses vacuum circuit breakers. They are fundamentally unsuitable for interrupting DC faults, unlike the other styles. Since there is no ‘current zero' cycle for DC, vacuum circuit breakers are unsuitable for breaking high DC voltages. The plasma arc will self-feed by condensing. By continuing to gasify the contact material, the plasma arc will self-feed[10].

## V. APPLICATIONS OF SWITCHGEAR

To separate or de-energize devices, power stations used basic disconnectors, also known as open knife switches. With the constant rise in power levels, manually opening such disconnectors became unsafe, necessitating the use of geared switches, which were then combined to form "Switchgear." It assists in protecting the appliances & electrical machines. The switch is used to manually open and close the electrical circuit in our home, while the electrical fuse protects the circuit from overcurrent and short circuit faults. Similarly, switching and protective equipment are required in any electrical circuit, including high-voltage electrical control systems. However, in high voltage and extra-high voltage systems, this switching and defensive scheme get more difficult in order to safely and securely interrupt high fault currents. Furthermore, any electrical power system requires a weighing, controlling, and regulating scheme from a commercial standpoint. The entire system is referred to as switchgear and power system safety. Switchgear safety is critical in today's power systems, from generation to transmission to delivery. The switchgear must carry, make, and split regular load currents in the same way as a switch does, as well as simple faults in the control grid. It also has the capability of measuring and controlling the different parameters of electrical power systems. Circuit breakers, current transformers, voltage transformers, safety relays, measuring devices, electrical switches, electrical fuses, miniature circuit breakers, lightning arresters or surge arresters, electrical isolators, and other related equipment are all used in the switchgear to ensure the protection of electrical systems. Any switching point in the electrical power grid necessitates the use of electric switchgear. Between the generating stations and load centers, there are different voltage levels and hence various fault levels. As a result, based on the system's voltage levels, different types of switchgear assembly are needed. Electrical switchgear is used in industrial works, industrial projects, domestic and commercial buildings, in addition to power grid networks to maintain safety in all fields.

## VI. CHALLENGES OBSERVED IN SWITCHGEAR

Even though switchgear acts as a medium of protection to various electrical devices, they themselves require to be monitored constantly to avoid any malfunctions. The most common problems faced in Switchgears are increased heat, increased pressure, and arc faults.

### A. *Temperature Rise*

Due to the extremely high voltage equipment present within the switchgear, the temperature has become a major concern. It is impossible to constantly track the switchgear temperature conditions with repeated visits to the setup since the issues that have occurred can worsen if not addressed immediately[11].

### B. *Vacuum/Over Pressure*

A small amount of pressure persists or escapes from within the switchgear containers during the suction of air, resulting in a significant decrease in switchgear performance. This could have an impact on future processes or may result in an explosion due to the accumulation of pressure in the undesired breach inside the system[12].

### C. *Arc Flash/Arching*

The medium between the opening contacts in a circuit breaker becomes heavily ionized during the opening of current-carrying contacts, allowing the interrupting current to pass along a low resistive path even after the contacts are physically isolated. An arc fault in switchgear triggers a long-term power outage, equipment destruction, and a safety threat to workers, this forces us to take precautions, well before so that any unwanted accidents can be prevented. Continuous monitoring of equipment and early detection of potential failures can facilitate a more proactive and comprehensive arc-flash prevention system[13].

## VII. CONCLUSION

The primary objective of this review is to brief about the Switchgear and the challenges observed in a switchgear. Electrical switchgear is a critical factor of electrical control systems worldwide, and it is used to both transmit and selectively separate electrical loads. In particular, the unexpected temperature rise at a particular location could indicate corrosion or some other type of defect. Thermal effects are especially visible in medium voltage switchgear used in distribution networks, where electrical currents may rise to few thousands of amperes. As a result, maintaining switchgear in good working order over the course of their long lives becomes crucial. Currently, switchgear bus temperature monitoring is either carried out on a periodic basis by means of manual inspections using IR cameras or by means of fibre optic systems that turn out to be too expensive[14]. One of the key outcomes of the online monitoring and diagnostic approach is a desire to improve the electrification system's maintenance strategy. As a result, a new modular solution for online condition monitoring should be introduced in order to implement condition-based maintenance for medium voltage (MV) switchgear and breakers. [15]. The solution can predict potential failures allowing maintenance schedule in advance by applying dedicated sensing technologies. Circuit breaker failure modes regard, for instance, open and close commands malfunction, charging mechanism malfunction, current interruption issues (contact wear), overheating, and overall health index of the monitored equipment should be calculated. The arc flash threat is related to electrical safety at the workplace and has received a great deal of attention as part of the safety programme for many installations[16]. An effective approach to the reduction of arc flash hazards in existing industrial and commercial facilities is a very important objective. Failure of electrical equipment is usually accompanied by abnormal temperature changes[17]. Therefore, the temperature monitoring of power equipment is the most effective and economical way of power equipment safety monitoring, which is of great significance to the safe operation of power equipment. This further leads us to management of the net-pressure inside the switchgear to avoid any over pressure which may lead to serious hazards, thus this should be maintained using affordable developed technologies where we can constantly monitor the system health of the switchgear and its components using online monitoring systems.

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## REFERENCES

[1] K. Matsushita, Y. Matsuura, T. Funabashi, N. Takeuchi, T. Kai and M. Oobe, "Study for the performance of high speed switchgear for protection of in-house generation system," Proceedings of 1996 IAS Industrial and Commercial Power Systems Technical Conference, New Orleans, LA, USA, 1996, pp. 91-95, doi: 10.1109/ICPS.1996.533941.

[2] Bolin, Phil & Koch, Hermann. (2008). Gas insulated substation GIS. 1 - 3. 10.1109/TDC.2008.4517307.

[3] Saurabh Saxena Maroof Ali Alok Singh Kapil Gandhi, “Various Types of Circuit Breakers used in Power System for Smooth Working of the Transmission Line,” MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2, No. 2, Aug. 2012, pp. (106-111) [4] S. Tokoyoda, T. Inagaki, K. Tahata, F. Page, K. Kamei, T. Minagawa

[4] IEEE Transactions on components, packaging and manufacturing technology —PART A, VOL. 21, NO. 1, MARCH 1998 33 "Arc Motion and Pressure Formation in Low Voltage Switchgear" ,Manfred Lindmayer and Joachim Paulke.

[5] Preve, Christophe & Lahaye, Gérard & Richaud, Myriam & Maladen, Romain & Penelon, Thibauld & Galas, Simon. (2017). Hazard study of medium-voltage switchgear with SF6 alternative gas in electrical room. CIRED - Open Access Proceedings Journal. 2017. 198-201. 10.1049/oap-cired.2017.0385.

[6] Wang, Jingqin & Wang, Li & Zhang, Guangzhi & Chi, Changchun. (2019). Study on prior information fusion method of low-voltage switchgear. Advances in Mechanical Engineering. 11. 168781401982667. 10.1177/1687814019826674.

[7] Ma, Canpeng & Moesch, Gilles & Cabaret, Bertrand & Tobias, J.. (2012). Innovative MV switchgear for today's applications. 1-4. 10.1109/CICED.2012.6508711.

[8] Ji, Tong & Xie, Wei & Wang, Xiaoqing & Zhang, Jinbo. (2017). The research of high voltage switchgear detecting unit. IOP Conference Series: Materials Science and Engineering. 222. 012021. 10.1088/1757-899X/222/1/012021.

[9] Djekic, Z.: 'Online circuit breaker monitoring system'. Master thesis, University of Novi Sad, Serbia, December 2007.

[10] Goh, Hui Hwang & Sim, Sy & Hamzah, Nur & Mazlan, Sulaiman & Ling, Chin & Chua, Qing & Goh, Kai Chen. (2017). Types of Circuit Breaker and its Application in Substation Protection. Indonesian Journal of Electrical Engineering and Computer Science. 8. 213-220. 10.11591/ijeecs.v8.i1.pp213-220

[11] Yu, Zhanqing. (2018). Temperature Rise Test and Analysis of High Current Switchgear in Distribution System. The Journal of Engineering. 2019. 10.1049/joe.2018.8371

[12] Y. Nakano, M. Kozako, M. Hikita, T. Tanaka and M. Kobayashi, "Estimation of Internal Pressure of Vacuum Interrupter by Measuring Partial Discharge Current," 2018 28th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Greifswald, 2018, pp. 611-614, doi: 10.1109/DEIV.2018.8537045.

[13] "Methods for Arc-Flash Prediction in Medium Voltage and Low Voltage Switchgear" Ghulam Amjad Hussain ,Aalto University publication series DOCTORAL DISSERTATIONS 221/2015.

[14] "Switchgear Condition Monitoring" M. Budyn , H. M. Karandikar , M. G. Urmson ABB Corporate Research1 (PL), ABB Inc.2,3 (USA) CIGRÉ Canada 21, rued#39; Artois, F-75008 PARIS CIGRE-115 Conference on Power Systems http : //www.cigre.org Vancouver, October 17- 19, 2010..

[15] "Modular online monitoring system to allow condition-based maintenance for medium voltage switchgear" Kevin Perdon 1, Massimo Scarpellini 2, Stefano Magoni 3, Luca Cavalli 4 ABB S.p.A., Via Friuli4, 24044 Dalmine (BG), Italy, 24th International Conference & Exhibition on Electricity Distribution (CIRED) 12-15 June 2017.

[16] A. M. Graham and M. Hodder, "Current methods for conducting an arc flash hazard analysis," Conference Record of the 2004 IEEE Industry Applications Conference, 2004. 39th IAS Annual Meeting., Seattle, WA, USA, 2004, pp. 1741-1748 vol.3, doi: 10.1109/IAS.2004.1348706. Osaka, Japan, 2020, pp. 130-134, doi: 10.1109/ICCRE49379.2020.9096479.

[17] "An Effective Approach to Reducing Arc Flash Hazards in Power Systems" Xiaodong Liang, Senior Member, IEEE, Bagen Bagen, Senior Member, IEEE, and David Wenzhong Gao, Senior Member, IEEE.