Design and Implementation of Indigenous Load Break Switch

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***Abstract*— A load break switch(LBS)is a crucial electrical component used in power distribution networks to provide a safe and efficient means of interrupting and isolating power flow in a circuit. Its primary function is to enable the manual or automatic disconnection of loads from the power source during maintenance, repairs, or in case of faults. This device plays a pivotal role in enhancing the reliability and safety of electrical systems. This abstract explores the fundamental principles and operation of load break switches, highlighting their various types, applications, and benefits. The discussion encompasses the key design features that allow for rapid and secure switching, ensuring the protection of equipment and personnel in the event of short circuits or overload conditions. Additionally, the abstract delves into the emerging trends in load break switch technology, such as the incorporation of smart and remote monitoring capabilities, as well as advancements in materials and construction techniques**

Keywords—LBS, power distribution network, rapid and secure switching, smart and remote monitoring.

I. INTRODUCTION

The purpose is designing a Load Break Switch for Solar PV application. Solar PV plants have a high voltage but comparatively low current. Hence, using a LBS instead of a Circuit breaker will prove cost effective and thus provide the benefits to the customers. Product development is a very complex process ranging from fixing the specifications to selecting the materials and designing. Each component needs to be designed individually. The process of creating components in AutoCAD begins with an individual sketch of the desired geometry, whether it’s a 2D shape or a complex 3D model. The user defines parameters, such as dimensions, to make the component dynamic, allowing for easy adjustments as needed After the Auto-Cad part, the components are fabricated and then assembled. This assembly in this case, the Load Break Switch needs to be tested in order to make it available in the market. Various tests are carried out on the switch by certified agencies thus making it certified for industrial applications. Load Break Switch is a pretty crucial product. In simple terms, it is just like our domestic buttons except with a very robust mechanism and very high voltage and current ratings. The LBS if placed properly and given feedback, can even work as a reliable and safe substitute to the circuit breaker. The CB is four to five times costlier than a LBS. Thus using LBS even with feedback will prove very cost efficient and thus reap the benefits to the customers.

The objective when designing a load break switch encompasses several key considerations. First and foremost, it is essential to create a switching device that is highly dependable and efficient in its operation. Safety is a paramount concern, ensuring that the switch can safely disconnect and isolate electrical circuits to protect both personnel and equipment from potential electrical hazards. The switch’s design must take into account its ability to withstand mechanical stresses and environmental factors, as it may be deployed in various conditions.

Quick and reliable switching is also a crucial objective, minimizing downtime during maintenance or fault scenarios. Moreover, the load break switch should be engineered to handle the expected load capacity effectively. Depending on the application, enabling remote operation may be another goal to enhance control and convenience. Keeping maintenance requirements to a minimum is a practical objective to ensure the device’s longevity and efficient operation. Additionally, adherence to environmental standards and regulations, including features like effective arc-quenching, is vital to reduce environmental impact. Ultimately, the design of the load break switch should align with the specific needs and safety requirements of its intended application and promote seamless integration within the electrical system. Hence, along with the designing of a new product, designing it in India was also the main objective behind approaching the company. Load break switches are versatile, designed to handle load switching, which means they can make or break currents under load conditions, allowing for continuous power supply with minimal downtime during operations. These switches are typically compact and easy to operate, making them suitable for various electrical distribution and control systems. Reliability is a key objective, ensuring that load break switches can function effectively over an extended period, even in harsh environmental conditions. They must also meet safety standards and regulations, often featuring interlocking mechanisms to prevent accidental or unsafe operation. With a focus on longevity, load break switches are designed to withstand numerous operation cycles, guaranteeing their durability and extended service life in electrical systems.

II. SPECIFICATIONS

Unless otherwise stipulated in this Specifications, the A. B. Switches shall conform to IEC 62271-103 amended upto date. In case of difference, if any, between this specification and the IEC 62271-103 amended upto date the provisions of this specification will hold good.

Environmental Conditions:

a) Maximum ambient temperature 50^0C

b) Maximum ambient temperature in shade 45^0C

c) Minimum temperature of air in shade 350^0C

d) Maximum daily average Temperature 400^0C

e) Maximum yearly weighted average Temperature 320^0C

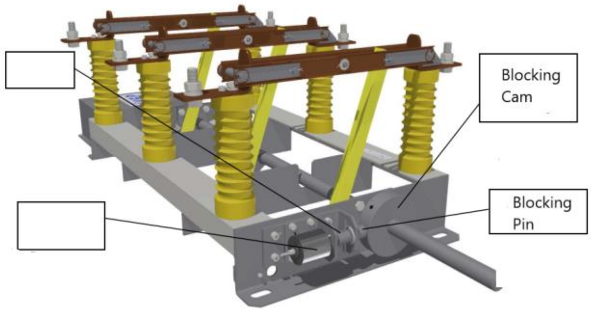
f) Relative Humidity 10 to 100 %

g) Maximum Annual rainfall 1450 mm

Air Humidity Maximum 92 % at 40 deg .C. Minimum 12 % Yearly average 44 %

Nominal voltage 11000 volt, Highest system voltage 12000 volt, Frequency 50 HZ, Short circuit level 25 kA r.m.s at 11kV System 3- Phase, 3 wires with neutral earthed through an earthing resistance of 21.1 ohm. limit the earth fault current to 300 Amps.

III. TESTS



Short-duration power-frequency withstand voltage tests: The switchgear and control gear shall be considered to have passed the test if no disruptive discharge occurs. If during a wet test a disruptive discharge (as defined by 4.1 of IEC 60060-1) on external self-restoring insulation occurs, this test shall be repeated in the same test condition and the switchgear and control gear shall be considered to have passed this test successfully if no further disruptive discharge occurs.

Impulse tests: The following test procedure B of IEC 60060-1, adapted for switchgear and controlgear that have self-restoring and non-self-restoring insulation, is the preferred test procedure. The switchgear and controlgear has passed the impulse tests if the following conditions are fulfilled: – each series has at least 15 tests; – the number of disruptive discharges shall not exceed two for each complete series; – no disruptive discharge on non-self restoring insulation shall occur. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge. This procedure leads to a maximum possible number of 25 impulses per series.

Dielectric tests- Dielectric tests of the switchgear and control gear shall be performed in compliance with IEC 60060-1, unless otherwise specified in this standard.

Ambient air conditions during tests Reference shall be made to IEC 60060-1 regarding standard reference atmospheric conditions and atmospheric correction factors. For switchgear and control gear where external insulation in free air is of principal concern, the correction factor Kt shall be applied. The humidity correction factor shall be applied only for the dry tests where insulation in free air is of principal concern

Corrosion Caution has to be taken against corrosion of the equipment during the service life. Corrosion shall not affect the functionality of the equipment under defined service conditions. All bolted or screwed parts of the main circuit and of the enclosure should remain easy to disassemble, as applicable. In particular, galvanic corrosion of materials in contact shall be considered because, for example, it may lead to the loss of tightness or increased contact resistance, reference is made to Annex H

Rated impulse withstand voltage- phase-to-earth constitutes the main part of the test voltage and is applied to one terminal; the complementary voltage is supplied by another voltage source of the opposite polarity and applied to the opposite terminal. This complementary voltage may be either another impulse voltage, the peak of a IS/IEC 62271-1: 2007 56 power-frequency voltage or a d.c. voltage. The other poles and the frame are earthed.

Power-frequency voltage tests- Switchgear and control gear shall be subjected to short-duration power-frequency voltage withstand tests in accordance with IEC 60060-1. The test voltage shall be raised for each test condition to the test value and maintained for 1 min. The tests shall be performed in dry conditions and also in wet conditions for outdoor switchgear and control gear. The isolating distance may be tested as follows. –

Preferred method: In this case, neither of the two voltage values applied to the two terminals shall be less than one-third of the rated withstand voltage phase-to-earth. – **Alternative method:** for metal-enclosed gas-insulated switching device with a rated voltage of less than 72.5 kV and for a conventional switching device of any rated voltage, the voltage to earth of the frame Uf need not be fixed so accurately and the frame may even be insulated.

Switching impulse voltage tests- Switchgear and control gear shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse 250/2500 μs according to IEC 60060-1.

Wet tests shall be performed for outdoor switchgear and control gear only. The isolating distance shall be tested with the preferred method a) of 6.2.5.2. The insulation between poles shall be tested in dry conditions only according to Table 12 with a test voltage as per column 5 of Tables 2, by the preferred method a) of 6.2.5.2 in which the main part shall be equal to or higher than 90 % of the value given in column 4 of Tables 2. This value shall not exceed 100 % of the value indicated in column 4 of Table 2 without the consent of the manufacturer. The complementary part shall be applied to the adjacent phase in phase opposition in order that the sum of both voltages (main part and complementary part) is equal to the value indicated in column 5 of Tables 2. The actual voltage share shall be as balanced as possible. Any unbalanced share of the total test voltage is more severe. When voltage components are control gear shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 µs according to IEC 60060-1. When the alternative method is used to test the isolating distance of metal-enclosed gas insulated switching device with a rated voltage of less than 72.5 kV and of conventional switching device of any rated voltage, the voltage to earth of the frame Uf need not be fixed so accurately and the frame may even be insulated.

Artificial pollution tests for outdoor insulators No artificial pollution tests are necessary when the creepage distances of the insulators comply with the requirements of IEC 60815. If the creepage distances do not comply with the requirements of IEC 60815, artificial pollution tests should be performed according to IEC 60507, using the rated voltage and the application factors given in IEC 60815.

Voltage test as condition check When the insulating properties across open contacts of a switching device after the making, breaking and/or mechanical/electrical endurance tests cannot be verified by visual inspection with sufficient reliability, a power-frequency withstand voltage test in dry condition according to 6.2.6.1 and 6.2.7.1 across the open switching device at the following value of power frequency voltage may be appropriate, if not otherwise stated in the relevant product standards. For equipment with rated voltages up to and including 245 kV: – 80 % of the value in Tables 1a or 1b, column 3, for isolating distance and 80 % of the value in column 2 for other equipment. For equipment with rated voltages from 300 kV and above: – 100 % of the value in Tables 2a or 2b, column 3, for isolating distance; – 80 % of the value in Tables 2a or 2b, column 2, for other equipment.

Condition of the switchgear and control gear to be tested Unless otherwise specified in the relevant standards, the temperature-rise test of the main circuits shall be made on a new switching device with clean contacts, and, if applicable, filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

Measurement of the temperature and the temperature rise Precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the switching device and the variations in the ambient air temperature. For coils, the method of measuring the temperature rise by variation of resistance shall normally be used. Other methods are permitted only if it is impracticable to use the resistance method. IS/IEC 62271-1 : 2007 62 The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point. The temperature rise shall be recorded at regular intervals throughout the test when the calculation of the thermal time constant is needed. The surface temperature of a component immersed in a liquid dielectric shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

Ambient air temperature The ambient air temperature is the average temperature of the air surrounding the switchgear and controlgear (for enclosed switchgear and controlgear, it is the air outside the enclosure). It shall be recorded during the tests by means of at least three thermometers, thermocouples or other temperature-detecting devices equally distributed around the switchgear and controlgear at about the average height of its current-carrying parts and at a distance of about 1 m from the switchgear and controlgear. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

Short-time withstand current and peak withstand current tests- Main circuits and, where applicable, the earthing circuits of the switchgear and control gear shall be subjected to a test to prove their ability to carry the rated peak withstand current and the rated short-time withstand current. The test shall be made at the rated frequency with a tolerance of ±10 % at any suitable voltage and starting at any convenient ambient temperature.

Test current and duration-The a.c. component of the test current shall, in principle, be equal to the a.c. component of the rated short-time withstand current (Ik) of the switchgear and control gear. The peak current (for a three-phase circuit, the highest value in one of the outer phases) shall be not less than the rated peak withstand current (Ip) and shall not exceed it by more than 5 % without the consent of the manufacturer. For three-phase tests, the current in any phase shall not vary from the average of the currents in the three phases by more than 10 %. The average of the r.m.s. values of the a.c. component of the test currents shall be not less than the rated value. The test current It shall in principle be applied for a time tt equal to the rated duration tk of short circuit.

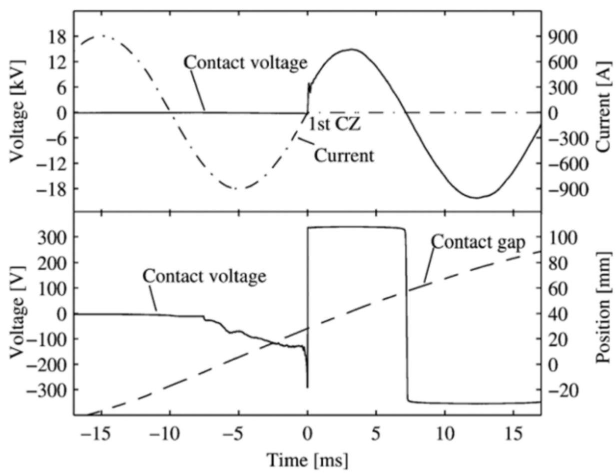
Tightness tests The tightness tests shall be performed in connection with the tests required in the relevant standards, typically before and after the mechanical operation test or during the operation tests at extreme temperatures. The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate Fp. Tightness test shall be performed with the same fluid and under the same conditions as used in service. If the fluid itself is not traceable additional traceable fluids might be added, for example helium. Where possible, the tests should be performed on a complete system at pre (or ρ re). If this is not practical, the tests may be performed on parts, components or subassemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart TC (refer to Annex E). The possible leakages between subassemblies of different pressures shall also be taken into account.

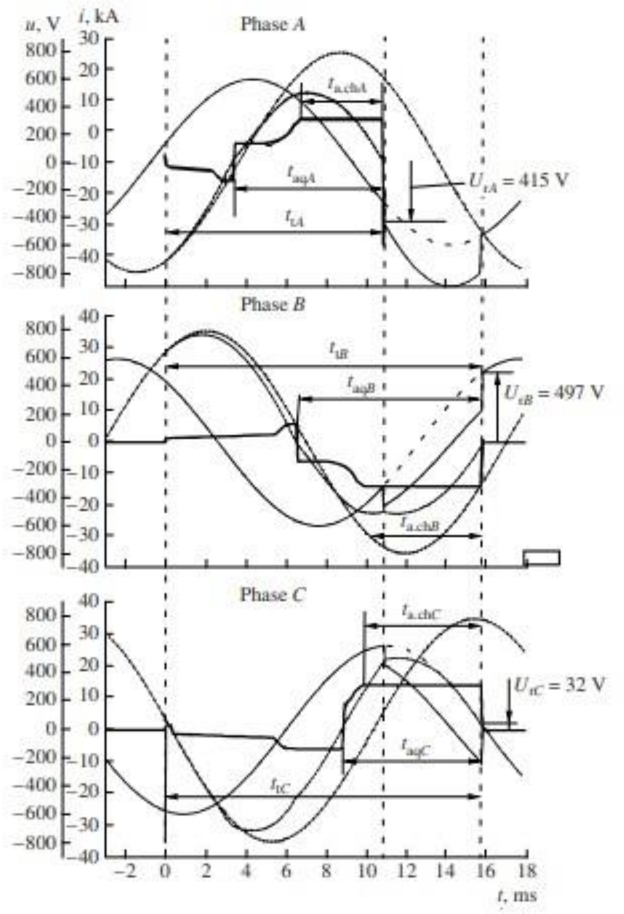
Final condition check- The power-frequency voltage withstand tests according to 6.10.6 shall be repeated after all other type tests have been completed, to confirm that there has been no reduction of performance during testing.

Dielectric test =-Auxiliary and control circuits of switchgear and control gear shall be subjected to short duration power-frequency voltage withstand tests. Each test shall be performed a) between the auxiliary and control circuits connected together as a whole and the frame of the switching device; b) if practicable, between each part of the auxiliary and control circuits, which in normal use may be insulated from the other parts, and the other parts connected together and to the frame. The power frequency tests shall be performed according to IEC 61180-1. The test voltage shall be 2 kV with duration of 1 min. The auxiliary and control circuits of switchgear and control gear shall be considered to have passed the tests if no disruptive discharge occurs during each test.

IV. CURRENT INTERRUPTION

In a successful interruption event within a typical circuit, the contact travel curve illustrates the journey of the contacts from initial closure to separation, highlighting the crucial moment of arc extinction at the first current zero (CZ) post-separation. Concurrently, the accompanying voltage and current waveforms provide a comprehensive depiction of the electrical dynamics during interruption. Notably, the lower graph depicts the contact voltage, acquired through a voltage divider with a constrained range, saturating at approximately 350 V to ensure accurate measurement within specified
limits.





the results of the calculation of the process of current interruption with a peak value of 35 kA at the short circuit in the three-phase system with a nominal supply-line voltage of 660 V. The first to go out was the arc in the A phase. The arc residence time within the arc chute is ta.ch ~ 4 ms. The recovery voltage reaches the value UrA = 415 V. Next, arcs in B and C phases go out simultaneously. The recovery voltage in the B phase is UrB = 497 V and, in the C phase, UrC = 32 V. The arc residence time within the arc chute in the B phase is ta.chB ~ 6 ms and, in the C phase, ta.chC ~ 7 ms. These periods by 2–3 times exceed a period of the arcquenching within the arc chute if the voltage Ua.ch exceeds the peak value of the supply-line voltage during the interrupting capacity test of the circuit breaker. Thus, the relation between voltages Ua.ch and Utm affects the arc quenching time taq and the recovery voltage Ur. The lower the Ua.ch/Utm ratio, the longer the process of the arc quenching and the higher the value of the recovery voltage.

V. MATERIAL SELECTION

The copper contacts employed in this system are crafted from electrolytic-tough pitch (ETP) grade copper, specifically designated as CW004A or ASTM C11040. Renowned for its exceptional purity exceeding 99.90% and a minimum electrical conductivity surpassing 101% IACS, ETP copper ensures optimal electrical performance. Additionally, ETP copper features a controlled oxygen content ranging from 0.02% to 0.04%, contributing to its superior conductivity and mechanical properties. Complementing the inherent qualities of ETP copper, a spring-loaded mechanism is integrated to uphold requisite contact pressure, ensuring consistent electrical connectivity. Furthermore, meticulous adherence to standard specifications dictates the hot-dip galvanization of MS components and hardware, thereby fortifying the switch assembly against corrosion and extending its operational lifespan.

Spring steel is a preferred material for switchgear owing to its remarkable resilience, high yield strength, and inherent flexibility. Its capacity to endure numerous compression cycles ensures sustained functionality throughout prolonged usage. Moreover, its robust mechanical properties guarantee reliable operation of switchgear mechanisms under diverse conditions. Furthermore, its malleability facilitates intricate component designs, while its corrosion resistance enhances durability in varied environments. Overall, spring steel presents a cost-effective solution, maintaining superior performance standards essential for electrical systems.

A. Material Specifications

TABLE I. CONDUCTIVITY AND RESISTIVITY AT DIFFERENT TEMPERATURES

Material	***Temperature (°C)***	***Conductivity (S/m)***	***Resistivity (Ohm/m)***
Copper	28	58*10^6	1.724*10^-8
	40	56.5*10^6	1.77*10^-8
Spring Steel	28	1.45*10^6	6.89*10^-7
	40	1.39*10^6	7.19*10^-7

VI. APPLICATIONS

Electrical Distribution Systems: Load break switches are extensively used in electrical distribution systems at various voltage levels, including high, medium, and low voltage. They are typically installed in substations, switchyards, and pole-mounted configurations to isolate sections of the distribution network for maintenance, repair, or troubleshooting.

Switching and Isolation: Load break switches are used for switching operations to connect or disconnect loads from the power source. They provide a means for isolating equipment such as transformers, capacitor banks, and overhead lines during maintenance or in emergency situations to ensure the safety of personnel and equipment.

Overhead Distribution Lines: Load break switches are commonly installed on overhead distribution lines to provide sectionalizing capability. By dividing the distribution network into smaller sections, utilities can minimize the impact of faults, improve reliability, and facilitate faster restoration of service in case of outages.

Ring Main Units (RMUs): Load break switches are integral components of ring main units, which are compact switchgear assemblies used in urban and industrial distribution networks. RMUs incorporate load break switches for sectionalizing purposes and can be equipped with other devices such as circuit breakers, fuses, and voltage indicators for enhanced functionality.

Transformer Protection: Load break switches are often employed as part of transformer protection schemes to isolate faulty transformers from the rest of the network. By quickly disconnecting the transformer in the event of a fault, load break switches help prevent damage to the transformer and minimize disruption to the supply.

Distribution Automation: Load break switches play a vital role in distribution automation systems, where remote monitoring and control of distribution networks are implemented. They enable remote operation for switching and isolation purposes, allowing utilities to respond swiftly to changes in load conditions, perform maintenance tasks remotely, and optimize the overall performance of the distribution system.

Safety and Maintenance: Load break switches are essential for ensuring the safety of maintenance personnel working on electrical equipment. By providing a visible break and physical isolation of the circuit, load break switches help prevent accidental contact with energized components, reducing the risk of electric shock and arc flash incidents.

Load Management: Load break switches can be used for load shedding or load transfer applications to manage peak demand and maintain system stability. By disconnecting non-critical loads during periods of high demand, utilities can optimize the use of available generation capacity and minimize the risk of overloading distribution equipment.

VII. CONCLUSION

In this paper, we try to summarize how a commercially viable load break switch can be made. This includes the required tests, material selection, its simulation for some parameters as well as some basic applications for a load break switch.

Making any product is not a simple process. It requires trial and error method. In the given case, the basic thermal simulation and electromagnetic parameters were found to be satisfactory. The Load Break Switch is designed for 11kV and 1250 A with 20kA breaking current capacity for 1ms. Hence, this will be used or can be used in any application satisfying the rated conditions.

With some basic market analysis, it was seen that the major load break switches available are either completely imported or imported as knock down units and then reassembled in the country. Thus this one can help to reduce that dependency.

Thus we can conclude successfully, that the product will be able to pass in the type testing by the required agency, hence making it commercially viable with an added aspect of indigeneity or the ‘Make In India’ initiative.

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