PERFORMANCE & ANALYSIS OF TOUCH PROOF ENCAPSULATED MEDIUM VOLTAGE VACUUM CONTACTOR

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ABSTRACT

In an electric power system, switchgear is the combination of electrical disconnector switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. This type of equipment is directly linked to the reliability of the electricity supply. The high-voltage circuit breaker was invented at the end of the 19th century for operating motors and other electric machines. The technology has been improved over time & there has been substantial growth in design & requirements of circuit breakers for various applications.

There are merits & demerits of different types of breakers over each other. Vacuum Circuit breakers are generally operated with the help of mechanical mechanism. Circuit breakers operated with mechanical mechanisms are having limited life because of wear & tear of mechanical linkages. Replacement & maintenance lead to larger down time and become very costlier affair. To overcome these applications based demerits of circuit breaker, contactors came into the pictures. Vacuum contactors are widely used in medium voltage switchgear. In this project work, primary aim is to understand the different requirements of vacuum contactors and different ways to achieve it. Also, we are going to cover design & simulation analysis of key components & features of medium voltage vacuum contactors like electromagnetic coils, vacuum interrupter, HT fuses, touch proof housing.

Keyword: - *Vacuum contactor Unit, International Electrotechnical Commission, Medium Voltage Vacuum Contactor, Vacuum Interrupter,*

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1. INTRODUCTION

1.1 Background

India is well on its way to becoming a global supplier of goods and services. An efficient power supply system is the key ingredient for a country's economic growth and quality of life. Current installed transmission capacity for evacuation is an emerging bottleneck, further outdated distribution system with huge losses is a cause of serious concern, and hence there is an urgent need for enhancement and Upgradation of the transmission and distribution infrastructure to evacuate requirement of additional power across the country. The switchgear industry continues to innovate and upgrade its products to meet the evolving/future needs of its customers.

The smart substation concept is built on state of the art automation technologies for substations, and should enable a more reliable and efficient protection, monitoring, control, operation, and maintenance of the equipment and apparatus installed within the substations, as well as rapidly respond to system faults and provide increased operator safety. So, in this work we have considered enhancement and Upgradation of important equipment of smart substation. Medium voltage Vacuum Contactors is one of the advanced solutions for crucial requirement of switchgears.

In an electric power system, switchgear is the combinations of electrical disconnecting switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. In last few years, reputed international switchgear manufacturers have introduced their latest and Compaq design of VCUs (Vacuum Contactor Unit) and allied products in Indian market. These products with good industrial design and better aesthetics are perceived as better products.

1.2 Objectives

Challenges in Designing Vacuum contactor is required to be accurately conceptualised. Each and every component shall meet the desired function. As system voltage of vacuum contactor increases, required characteristics like Power frequency High voltage, lightning impulse voltage, partial discharge effects and temperature rise performance of main circuit and auxiliary circuit increases accordingly. Operating time is also become important and subject to the various affecting parameters at that instant. The success of accurately designed vacuum contactor for higher system voltage is depends on the accurate design of all parameters and reliability of auxiliary circuit. The work presented in this dissertation focuses on design and analysis of vacuum contactor and system upgradation to 12kV. In this work, various important validation test as per IEC standard is covered.

Switchgears are fundamental equipment's in Power Transmission Network. In an electric power system, switchgear is the combination of electrical disconnects switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. This type of equipment is directly linked to the reliability of the electricity supply. As India has ambitious plan of addition of generation capacity with matching transmission capacity, frequent failure of any equipment may affect evacuation of generation and finally inconvenience to customer. The reliable performance of vacuum contactor is the key to the success of correct functioning of reliable switching function. The specification of vacuum contactors should be realistic to meet the functional requirements for the given application. Over-specification results in costly and bulky design without much value addition. The ideas explored here will be helpful to practicing engineer to specify correct parameters of vacuum contactors. This will result in procuring the most economical vacuum contactors without sacrificing end user requirements.

2. SYSTEM DEVELOPMENT

2.1 Vacuum Contactor

Vacuum contactors utilize vacuum bottle encapsulated contacts to extinguish the arc. This arc extinguishing allows the contacts to be much smaller and use less space than air break contacts at higher currents. As the contacts are encapsulated, vacuum contactors can be used fairly in the highly polluted applications, such as mining.

2.2 Operating principle

When current passes through the electromagnet, a magnetic field is produced; this attracts the moving core of the contactor. The electromagnetic coil draws more current initially, until its inductance increases when the metal core enters the coil. The moving contact is propelled by the moving core; the force developed by the electromagnet holds the moving and fixed contacts together. When the contactor coil is de-energized, gravity or a spring returns the electromagnet core to its initial position and opens the contacts. For contactors energized with alternating current, a small part of the core is surrounded with a shading coil, which slightly delays the magnetic flux in the core. The effect is to average out the alternating pull of the magnetic field and so prevent the core from buzzing at twice line frequency.

In high voltage contactors, working concept is based on electromagnetic principle similar to low voltage contactors. There is one fixed electromagnet and it will be magnetized once it will supply with control voltage. After magnetizing the electromagnet, it will actuate the closing mechanism of medium voltage contactors and it will make the contact in vacuum interrupter & lead to switch ON the contactors. As a result of this coil fixed part attract the movable part till the control voltage is in ON condition.

In case of the latch type contactor, electromagnetic coil is used to close the contactor after closing contactor it will get cut off. To hold the contactor in close position, there is one additional external mechanical latch assembly provided. The function of latch assembly is to hold the contactor till tripping command is given. Additional tripping arrangement is provided to trip the mechanical latch arrangement in contactor. These types of contactors are economical, as they will not consume power for long time. Once the contactor gets closed, control power supply to closing coil will get disconnected. These types of contactor are used in the long duty applications.

In case of the Non-latch type contactors, there will be coil in coil concept of electromagnetic coil. There will be two separate coils mounted on each other. First coil will be used for Picking Up the contactor to close condition and second coil will be used holding the contactor in close position. If supply to closing coil gets cut off, it will release the contactor to open condition. There will not be latching mechanism provided to hold the contactor. In this type of contactor, there is a requirement of continues control supply.

2.3 Typical Constructional Details

The vacuum contactor consists of three Epoxy cast Poles, each individual epoxy cast Pole forms a switching pole. These epoxy cast consist of main current caring components with vacuum bottles are mounted on rigid epoxy base plate to further improve insulation properties. This part is the further attached to a very simple, compact, durable and maintenance free electromagnetic coil and its mechanism. The compact vacuum contactor unit featured with minimum number of components which enhance the mechanical life of the contactor. There are two operating coils in the contactor, both are used to switch as well as hold the vacuum contactor in “ON” condition. The durable opening springs open the contacts very fast so as to open the circuit effectively to improve the response time of your control circuit.

2.3.1 Encapsulated Housing

Housing assembly also known as Pole assembly or power path assembly. This assembly consists of main housing body made up of Epoxy having two ends cover (front & rear) mounted on both sides. HT fuse and vacuum interrupter has kept inside the epoxy housing, to make it encapsulated. The current transfer path is from top conductor to HRC fuse with fuse holding clamp, then it is transfer from fuse to fuse clamp then vacuum interrupter and finally it flows to flexible conductor and bottom conductor.

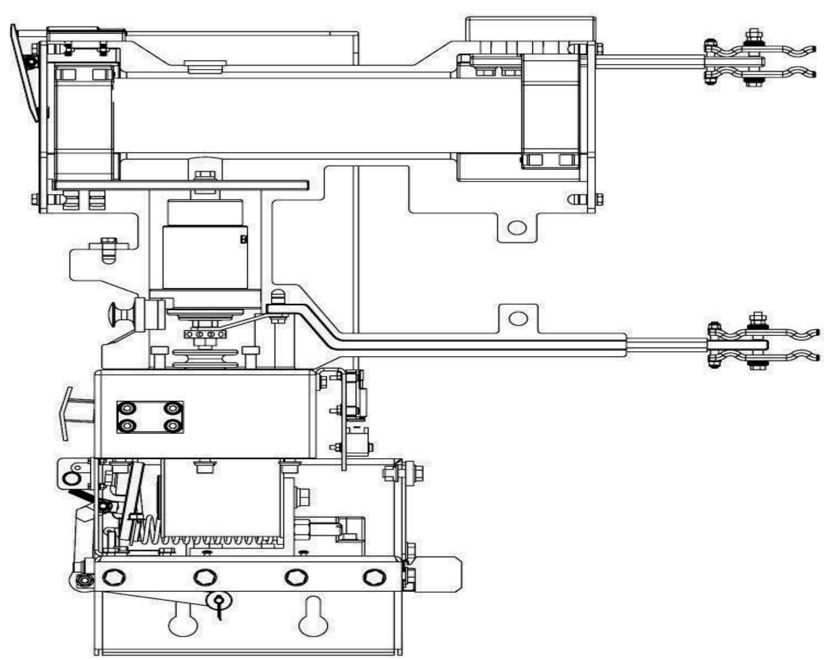

Fig. 2.3.1 Typical Constructional Details of VCU

At bottom of the flexible conductor, there is an insulated drive rod which is important components for insulating High voltage potential and earth parts. All current carrying parts have made of up copper material with silver or tin plating.

3 PERFORMANCE ANALYSIS

3.1: Experimental Analysis with Different Tests

- Routine Tests

- Type Tests

3.1.1 Routine tests on Vacuum Contactors

There are different routine test required to be performed on the Vacuum contactors. Different types of tests are decided as per standard. Designer is specifying typical requirements for accurate and reliable function of product. Following are details of routine test on vacuum contactors.

Table 3.1.1. Experimental Routine Test Results

Routine Test Report				
Sr. No.	**Description**	**Parameters**	**Criteria**	**Result**
	VC Specification	Rated Voltage Level	12	Kv
1	Vacuum Interrupter	Serial No.: R Phase	Vis Make / Type:	A142
		Y Phase	Eaton (Wl- 36156a)	A143
		B Phase		A144
2	Coil Resistance	Closing Coil	177 To 193 Ω	180 Ω
		Opening Coil	45 To 50 Ω	45 Ω
3	Contact Resistance	R Phase	< 100	90μω
		Y Phase		85μω
		B Phase		90μω
4	Min./Max. Operation Voltage	Closing Coil	Pass 85% Rated Voltage	Yes
		Opening Coil	Pass 70% Rated Voltage	Yes
		Closing/Opening	Pass 110% Rated Voltage	Yes
5	Closing Charateristic	Closing Voltage	100% Rated Voltage	220v Dc
		Closing Time	40 - 60 Ms	55 Ms
		Closing Coil Current	5a To 10a	8 A

6	Opening Characteristics	Opening Voltage	100% Rated Voltage	220v Dc
		Opening Time	80 - 100 Ms	90 Ms
		Opening Coil Current	1a To 5a	1 A
7	Operation Checks	Electrical Close / Open	Smooth Operation	Yes
		Mechanical Latch	Smooth Operation	Yes
		Racking Operation	Smooth Operation	Yes
		Amp. Rating Interlock	Rating Error Prinventor	Yes
		Plug Interlock	Easy To Connect / Disconnect	Yes
		Hardware	Proper Fastening	Yes
		Counter	Operational	Ok
		Racking Mechanism	Smooth Operation	Yes
8	Power Frequency	Aux Circuit	2kv	Pass
		Main Circuit	28kvp/75kvrms	Pass

3.2 Type Tests on Vacuum Contactors

a. Short-Circuit Withstand Capability Test

It is the RMS value of the current which the switchgear and controlgear can carry in the closed position during a specified short time under prescribed conditions of vacuum contactors.

Table 3.2.1. Details Of STC Test

Test	Current Through Test Equipment in kA (Peak/rms)	Duration of Short Circuit in Second (S)
Dynamic Test	20.0	0.3
Thermal Test	8.0	2.0
Observation During Test	No Abnormality has notice	

b. Power Frequency High Voltage withstand Test.

Test was carried out on 12kV vacuum contactors prototype to evaluate the effectiveness. Following were the parameters of sample tested.

Table 3.2.2. Details Of Sample Tested

Sr. No.	Sample Parameters	Values
1	Rated voltage	12kV
2	Rated lightning impulse withstand voltage	75kV
3	Rated power frequency withstand voltage	28 kV
4	Rated frequency	50Hz
5	Rated normal current	400A
6	Width of a function unit	600 mm
7	Distance between phases	165 mm

Test arrangement is made up with the help of High voltage kit. Following figure shows the test setup.

Table 3.2.3. High Voltage Test Summary

Sr. No.	HV	Earth	VI Condition	Test Voltage	Result
1	R-r	Body & Other Phases	Close	28kV	Pass
2	Y-y	Body & Other Phases	Close	28kV	Pass
3	B-b	Body & Other Phases	Close	28kV	Pass

After above test, following were the observation,

Observations **:** No disruptive discharge was noticed during the test.

Conclusion : The test result indicates that the tested sample complies with the requirement of the relevant clause of IEC 62271-100, 62271-200.

c. Lightening Impulse Voltage withstand Test.

After Experimental analysis, we have made following changes to improve the lightning impulse performance.

- Designing New Insulator for 75kVpk.
- Selecting New Vacuum Interrupter to withstand 75kVp.
- New Front Epoxy cover and Polycarbonate sheet as an insulating barrier.
- New Epoxy housing with added thicknesses to improve di-electric performance.

New prototype is again tested to withstand the di-electric test. After testing it is found that, sample is conforming the requirement. Test was carried out on 12kV vacuum contactors prototype to evaluate the effectiveness. Following were the parameters of sample tested.

Table 3.2.4. Details Of Sample Tested

Sr. No.	Sample Parameters	Values
1	Rated voltage	12kV
2	Rated lightning impulse withstand voltage	75kV
3	Rated power frequency withstand voltage	28 kV
4	Rated frequency	50Hz
5	Rated normal current	400A
6	Width of a function unit	600 mm
7	Distance between phases	165 mm

Table 3.2.5. Result Comparison Between 7.2 kV VCU With 12 kV VCU

Sr. No.	7.2 KV Vacuum contactor unit (Existing)	12 KV Vacuum contactor unit (Implementation)
1	Temperature Rise of vacuum contactors at different components	Temperature Rise of vacuum contactors at different components and points is within limit.
2	Contact Resistance values of VCU from Top arm to Bottom arm of individual phase 180 Ω.	Contact Resistance values of VCU from Top arm to Bottom arm of individual phase is coming 140 Ω to 150 Ω.
3	Pick up voltage of closing coil shall be 187V in DC Supply and 196V in AC Supply.	Pick up voltage of closing coil shall be 154V in DC Supply and 160V in AC Supply.

4	Insulation system of VCU is designed for 28kVrms for 1 minute and 75kVp impulse 15 positive and negative shot as per IEC.	New Design of VCU can withstand up to 35kVrms for 1Minute and 83kVp for 15 positive & Negative Cycle.
5	Drop out voltage of closing coil shall be 75% of rated voltage.	In experimental analysis drop out voltage of coil is 58% of rated voltage.
6	Partial Discharge value of VCU shall be below 10pC. (Pico Columb)	PD Value of VCU is observed 6pC.

3.3 Justification for Difference in Results

Table 3.3.1. Justification For Difference in Results

Sr. No	Requirements as per standard	Experimental Results
1	Temperature Rise of vacuum contactors at different components and points were assumed to be with 10% safety factor.	In experimental analysis it is found that temperature rise of different components are with safety factor of more than 10%.
2	Contact Resistance values are calculated considering theoretical values of resistance per meter.	In measurement actual values of resistance are less because of use of High Density High Conductivity (HDHC) copper.
3	Pick up voltage of closing coil is considered to be 85% of rated voltage.	In experimental analysis pick up voltage of coil is 70% of rated voltage. This is to overcome abnormality during operation.
4	HV & Impulse withstand capability of VCU is 28kVrms and 75kVp	New Design of VCU can withstand up to 35kVrms for 1Minute and 83kVp for 15 positive & Negative Cycle.
5	Drop out voltage of closing coil shall be 75% of rated voltage.	Over design is required to overcome abnormality during operation.
6	Density of materials *i.e.* is taken from raw material supplier's data.	Practical Values are well within the limit
7	Partial Discharge value of VCU shall be below 10pC. (Pico Column)	PD Value of VCU is observed 6pC because of accurate design & manufacturing of insulating materials.

4. CONCLUSIONS

This project has summarized the various practices used for the design, maintenance, diagnostics, and care of the Vacuum contactors. A basic objective of this work is to overcome the disadvantages/drawbacks of the present 7.2kV vacuum contactors for range Upgradation to 12kV. With the desired modifications, vacuum contactor is capable of withstanding requirements mentioned in standard. It also improves power quality and prevents switchgear and other system components from severe stresses. We have complete modifications in all components to withstand higher rating of 12kV with validation on actual prototype. Following are the objective of project,

1) To provide an encapsulated mould assembly for a vacuum contactor with proper electrical insulation to withstand 28kVrms and 75kVp voltage.

2) To provide an encapsulated mould assembly which provides more electrical insulation, free from dust and mechanical support to vacuum contractor.

3) To provide an encapsulation and protection to a high rupturing capacity (HRC) fuse, vacuum interrupter/arching component and corresponding current carrying part from high voltage.

4) To provide an encapsulated mould assembly for preventing said assembly from the corona effect which is harmful for insulation body.

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