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Elimination of Malfunctioning of Density meters During Circuit breaker Operation

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Abstract---The SF6 Circuit breakers used in the transmission lines employ a density meter for monitoring the pressure and temperature level of the SF6 gas used. The density meter is subjected to certain malfunctioning because of some environmental features. We are dealing with the problems associated with the malfunctioning of density meters and the possible solutions that can be adopted to obtain continuous power supply.

Keywords---SF6 circuit breaker, Density meter, Low alarm contacts, Lockout contacts, Contactor coil, Contact multiplier, Off delay timer.

I. INTRODUCTION

The main objective of this project is to find out the best feasible solution to overcome the interruption of power supply caused by the malfunctioning of density meters used in SF6 circuit breakers .The circuit breakers used along the transmission lines are mounted above a certain height. Because of this, the density meter is subjected to some vibrations. The change in the external environment also adds to these vibrations and causes the malfunctioning of the density meter which creates an interruption in the power supply for about a few seconds. Our project explains about the methods that can be adopted to compensate or avoid this interruption in the power supply. We have proposed about three solution methods that can be implemented.

II. TYPES OF CIRCUIT BREAKERS

There are many different types of circuit breakers available and they are used depending on the applications.

Some of the types of circuit breakers are:

- *Oil circuit breaker*
- *Air blast circuit breaker*
- *Vacuum circuit breaker*
- *SF6 circuit breaker*

In our project, We are dealing with SF6 circuit breakers and SF6 density meters that are used in the transmission lines.

III. SF6 CIRCUIT BREAKER

An SF6 Circuit breaker is a device which operates in the presence of Sulphur Hexafluoride or SF6 gas. The SF6 gas has many advantages in their properties and hence they are widely employed in transmission lines.

A. Properties of SF6 gas

The SF6 gas has high electronegativity and excellent insulating properties. Hence it has high affinity towards absorbing of free electron. When a free electron collides with a SF6 gas molecule, it gets absorbed by the gas molecule and forms a negative ion. Since this negative ion is heavier than the free electron, the overall mobility of the particle in SF6 gas is less compared to that in the other gases. The mobility of the charged particle is what is responsible for the conduction of current through a gas. Hence for the charged particles which are heavier and less mobile, the SF6 gas has the ability to acquire good dielectric strength. In addition to this, it also has the unique property of fast recombination after the source energizing the source is removed. The SF6 gas also has a very good heat transfer property. Owing to less mobility of charged particles, the SF6 gas has low gaseous viscosity and hence can efficiently transfer heat by convection.

Hence, due to high dielectric strength and high cooling effect of the gas, SF6 is approximately about hundred times more efficient arc quenching media than air. The SF6 circuit breaker is most widely used in a range of medium voltage and high voltage electrical power systems due to these unique properties of the SF6 gas.

B. Working of SF6 circuit breaker

In earlier times, the working of SF6 circuit breaker was similar to the Air blast circuit breaker to some extent. It involves a high pressure reservoir and a low pressure reservoir. The SF6 gas was compressed and stored into the high pressure reservoir. When the circuit breaker operates, the highly compressed gas is released through the arc in breaker and gets collected into the low pressure reservoir. It is again pumped back into the high pressure reservoir for reuse. The working of SF6 circuit breaker in modern times is a little bit different from those at earlier times. It involves puffer type design for the easy operation of SF6 circuit breaker. In this design, the energy of the arc is utilized to develop pressure in the arc chamber for arc quenching purposes.

The SF6 gas at rated pressure is filled into the circuit breaker. The breaker consists of two fixed contacts that are fitted with a specific contact gap between them. It also consists of a sliding cylinder to bridge these two contacts. The cylinder can slide upward and downward axially along the contacts. The cylinder has a stationary piston inside which is connected with the other stationary parts of the circuit breaker, in such a way that its position is not changed during the movement of the cylinder. Since the piston is fixed and the cylinder is movable, there are chances that the internal volume of the cylinder is changed when the cylinder moves or slides.

During the opening of the breaker, the sliding cylinder moves downwards against the position of the fixed piston and because of this the volume of the cylinder gets reduced and produces compressed SF6 gas inside the cylinder. The cylinder also employs a number of side vents that are blocked by the upper fixed contact in the closed position. As the cylinder moves further downwards, these side vents get unblocked and cross the upper fixed contact. The compressed SF6 gas will come out of the cylinder through the vents in high speed towards the arc and passes through the both the fixed contacts. The arc gets quenched during this flow of the SF6 gas. During the closing of the breaker, the sliding cylinder slides upwards against the position of the fixed piston and hence the volume of the cylinder gets increased and produces a low pressure inside the cylinder compared to that of the surrounding. This pressure difference causes the SF6 gas from the surroundings to enter into the cylinder. The SF6 gas with higher pressure will come out through the axial hole of both the fixed contacts and enters into the cylinder through the side vents and the arc gets quenched.

C. Advantages of SF6 circuit breaker

- The interrupting chamber is so simple that it does not require an auxiliary breaking chamber
- Higher performance can be obtained with a reduced number of interrupting chambers
- The circuit breaker has high electrical endurance in such a way that it can operate for atleast 25 years without any reconditioning
- High reliability and availability
- Low noise levels

IV. DENSITY METER

The density meter is an economical and reliable method to monitor the pressure and temperature level of the SF6 gas used inside the SF6 circuit breaker.

The instrument is generally used to measure the density of SF6 gas inside sealed tanks. They are designed to monitor the SF6 gas density and to provide signal outputs when the density is not within tolerable range of threshold values.

A. Functions of SF6 density meter

The density meters are used to provide protection to the high voltage circuit breakers against the loss of the SF6 gas density. The gas is usually contained in a container of fixed size and hence any change in temperature will affect the pressure inside the tank. Whenever the temperature and pressure of gas falls below a predetermined level, the device will alarm or lockout depending on the requirement.

B. Advantages of SF6 density meter

- Temperature compensation is not required
- The device has high resistance against vibration and shock
- Requires less maintenance
- Do not require recalibration of the switch points
- Monitoring the density of other gases are also possible

V. MOUNTING OF CIRCUIT BREAKER

The transmission lines are provided with circuit breakers for the purpose of fault detection and interruption of power flow in the case of any faults. Our project here deals with the SF6 circuit breaker and the SF6 density monitor that are placed in the transmission lines.

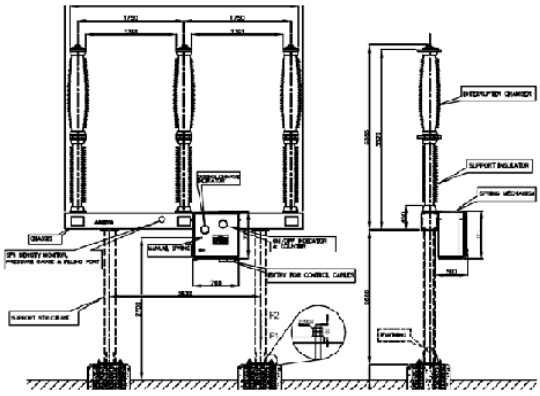

Fig. 1 Mounting of circuit breakers

The circuit breakers are usually mounted at a height of about 2.7 m above an insulator support. The SF6 circuit breakers are usually mounted on the arena and two pillars are provided to support the circuit breaker. SF6 density meters are also fitted along with the circuit breaker in a position as shown in the figure. The circuit breaker is provided with ports for the filling of SF6 gas into the chamber.

A. Density meter contacts

The SF6 density meter consists of NC and NO contacts. When SF6 gas is not filled into the circuit breaker i.e., at no SF6 condition or state, the density meter consists of 1 NC (Low alarm) and 2 NO (lockout) contacts. These contacts in the presence and absence of SF6 gas are as shown in figure 2. Once when the SF6 gas is filled into the CB through the port, the NC contact of the density meter becomes NO and the NO contacts become NC. With the SF6 gas at rated pressure level, which is 0.74Mpa, abs.at 20^{o} C, the Low alarm contact P1 (1&2) contacts are in open state and Lockout contacts P2 (3&4 and 5&6) contacts are in closed state. The SF6 circuit breaker also consists of contactor coils, namely A1 and A2.

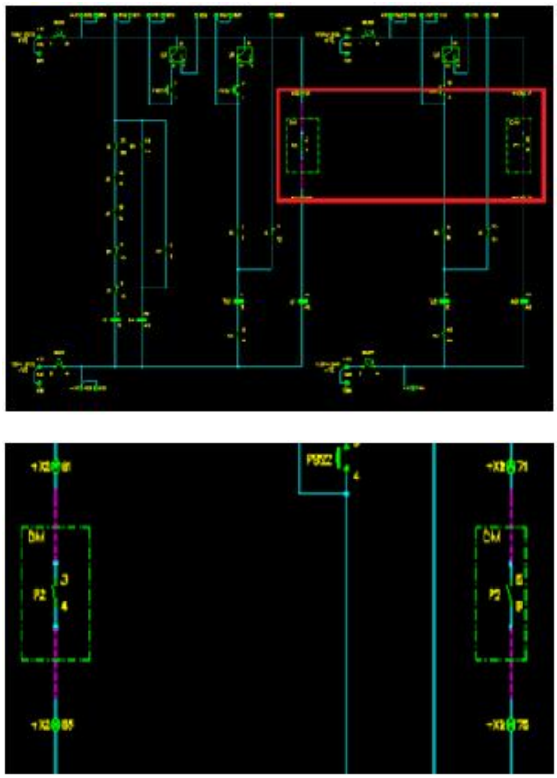

Fig. 2 Existing schematic of the density meter contacts

B. Normal operation of the density meter

Closed contact P2 energizes the contactors A2 & A3 and opens the A2, A3 (21&22) contacts when the gas is at the required pressure level.

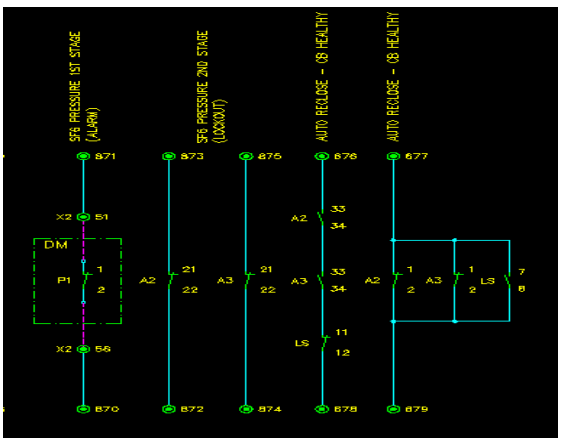

Fig. 3 Contactor coil arrangement

When any reduction in the pressure level of SF6 gas is observed, then the Lockout contacts P2 (3&4 and 5&6) gets opened. Because of this, the contactor coils are no more energized by the P2 contacts. Hence the contactor coil de-energizes and the CB gets tripped. The density meter has the provinces to give out alarm whenever the contactor coils get de-energized so that manual operations can be carried out to maintain the pressure level of the SF6 gas inside.

VI. MALFUNCTIONING OF DENSITY METER

Since the circuit breakers are mounted above a certain height and also due to the fast operation and the external environmental conditions, there will be some vibrations occurring in the transmission system. These vibrations cause the P2 contacts to get opened up for a moment even with the SF6 gas under normal pressure level, due to which the contactor coil de-energizes and the trip signal will be sent. The circuit breaker gets tripped only for a very short duration of about few micro seconds. But this unnecessary tripping causes interruption in the power supply which is undesirable. Hence this interruption in the power supply has to be compensated.

VII. POSSIBLE SOLUTIONS

Although the opening of the P2 contacts of density meter still having the gas at the rated pressure, is for a very short duration, the power interruption should be prevented from occurring. The malfunctioning of the density meter can be prevented by using both mechanical and electrical solutions. The following are the electrical solution methods possible.

- By providing a capacitor across the contacts of the density meter.
- By providing off delay timer.
- By providing contact multiplier in SF6 gas low alarm.

A. Solution 1

The first solution is to connect a capacitor of about 10μF/450V across the contactor coil points A2 & A3. When the P2 contact gets opened, the capacitor will energize the contactor coils, thus preventing it from de-energizing and sending trip signal to the CB. Hence the capacitor will take care of the power supply without any interruption for that particular duration of time. The Discharge time of the selected Capacitors is greater than the lock out contact(s) open up time inside the SF6 density meter during the CB Operation thereby preventing the issue being faced. Along with the capacitors, a fusible resistor is also connected for safety measures.

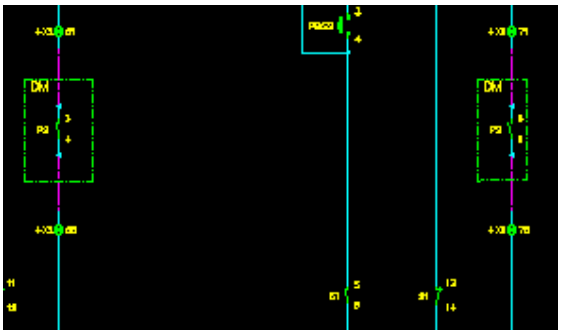

Fig. 4 Capacitor solution

B. Solution 2

The second solution is provided using an off delay timer. Off Delay timer T1 & T2 are connected to the SF6 gas lockout contacts P2 and the timer contacts are connected to the contactor coils A2 & A3 and their contacts are in turn connected to the remote alarms. With about 1 Sec time delay set-in at the timer, the A2 & A3 contactors will not be de-energize for that duration. Accordingly when the CB operates there would not be any lock out signal to SCADA.

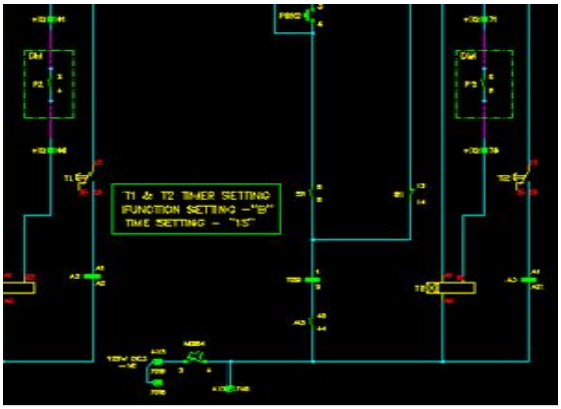

Fig. 5 Off delay timer solution

C. Solution 3

The third solution is by using a multiplier contact across the contacts. Contact multiplier K1 is connected to the SF6 gas low alarm contact for multiplying the SF6 gas low alarm contacts. Multiplier contacts K1is connected in series with SF6 gas lockout contacts which is connected to SCADA.Accordingly SCADA will not receive SF6 gas lockout alarm /trigger till SF6 gas pressure reduced to Low alarm level. (Despite the lockout contacts opens up for a moment). As the SF6 gas lockout is the second stage (Final stage) pressure measurement , the alarms contacts , which are the first stage indicators shall be used in series with the lockout alarm level to resolve the problem being faced.

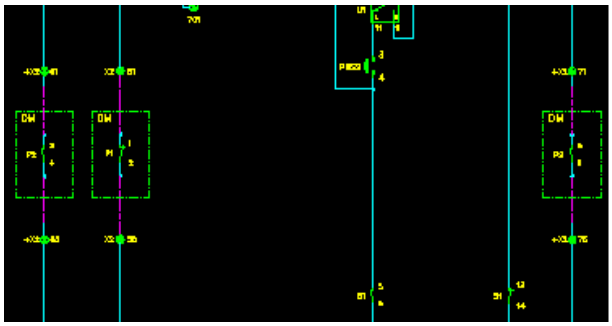

Fig. 6 Contact multiplier solution

VIII. CONCLUSION

Thus, the serious real life problem that currently exists in the transmission lines of some countries which include Germany, Thailand, etc. was discussed. The related information about this existing issue were collected and the three different possible solutions that can be implemented on the density meter were proposed to avoid the consequences of this malfunctioning. The capacitor solution among the three different solutions is found to be more feasible and advantageous than the other solutions. The hardware configuration of the SF6 circuit breaker with the capacitor is soon to be implemented. Hence, in the near future, this issue can be easily eliminated and the power transmission can take place without any interruption.

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