Surge protection of distribution transformers in South Africa

by Kevin Risi, Live Line Technology

Distribution networks in South Africa range from 3 kV - 33 kV, with 11 kV and 22 kV being the most popular. The majority of these reticulation networks are not protected against lightning by overhead shielded wires (the double conductor line above the three phase structure) which acts as a "shock absorber".

Surge arrestors, however, are ubiquitous, and are the preferred method of protection of overhead equipment against lightning induced overvoltages and improving line insulation co-ordination on poorly performing lines.

Surge arrestor theory

Modern surge arrestors comprise MOV (metal-oxide varistar) blocks stacked inside ceramic or polymer housings, designed to change their impedance to ground when over-voltage occurs. These protective devices protect insulated overhead equipment by eliminating voltage stress. Overvoltage occurrences are caused by lightning, utility switching, isolation arcing, or any other sudden change in electrical power flow on incoming AC power lines (spikes).

Surge arrestors have disconnect links at the bottom of each unit (also known as ground lead disconnectors - GLDs) that will remove the surge arrestor's ground tail from the line when the surge arrestor has come to the end of its life. This occurs when the MOV semi-conductive material inside the surge arrestor has broken down to a point where the power frequency current flowing through the unit generates enough heat inside the GLD to disconnect the unit. The settings of these disconnectors is a very precise science, as they should not operate too quickly, causing nuisance arrestor disconnection (where the unit is still healthy,) or too late, causing sensitive earth faults.

Surge arrestor theory suggests that arrestor lead lengths should be connected close to the overhead equipment, to reduce the *L di/dt* inductive voltage drop component in the lead wire and increase overvoltage protection efficiency. The correct positioning of surge arrestors on overhead lines requires proper analysis of an area before installation is carried out.

Correct configuration

The correct configuration of surge arrestors with respect to the MV fuse-cutout at the

A blown ground lead disconnector indicates a spent surge arrestor.

Fig. 1: Spent surge arrestors.

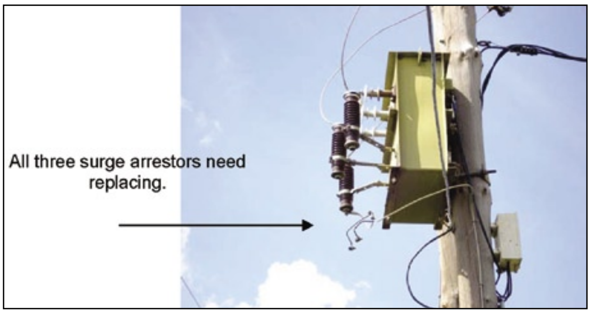

Fig. 2: Blown tails today, blown transformers tomorrow.

Year	1994	1995	1996	1997	1998	Total
Storm/ Lightning	366	392	497	524	607	2386
Electrical	12	9	32	17	14	84
Mechanical	7	10	21	8	8	54
Human	3	3	9	4	3	22
Nature	3	3	9	4	3	22
Animals	4	2	16	19	12	53
Unknown	198	202	181	198	300	1079

Fig. 3: Reasons for transformer loss at a particular utility.

pole mounted transformer is a very important point. Everything must be done to ensure that the surge arrestor is kept healthy at all times so that it can deal with the lightning surge protection component when needed. Drop-out fuses can handle up to 100 A continuously on a distribution system, whilst the surge arrestor works with surge current peaks up to 10 kA. The fuse should never be incorrectly rated or allowed to disconnect in such a manner that the surge arrestor fails to perform its full overvoltage function when lightning occurs.

Surge arrestor maintenance

South African electrical utilities are plagued with poor surge arrestor maintenance. This is due to the fact that outages need to be arranged to change surge arrestors and this process takes several hours. This lack of maintenance is a major contributor of losses to overhead equipment (Fig. 2).

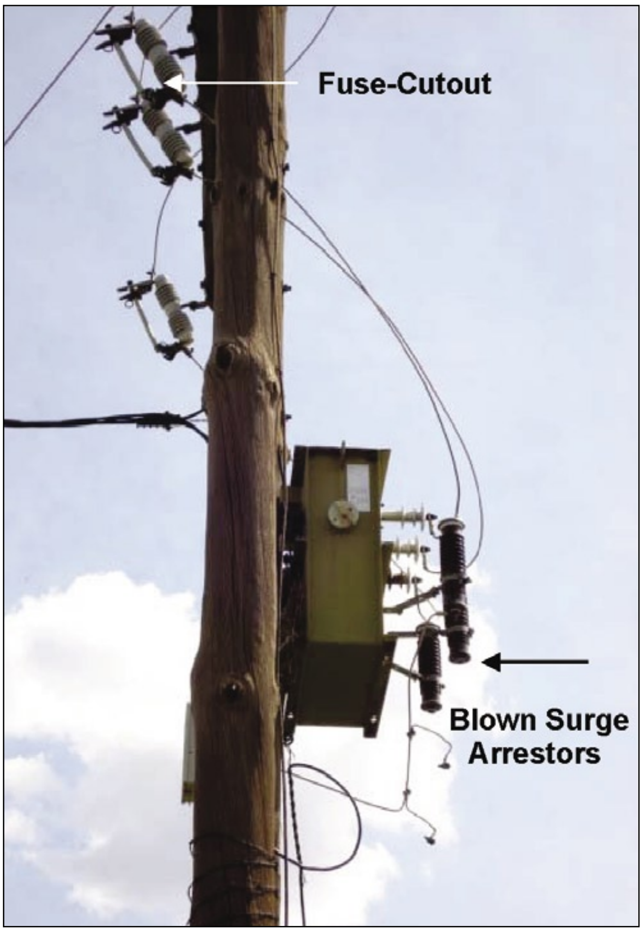

Fig. 4a: Typical configuration with cut-out fuse protecting with both transformer and arrester.

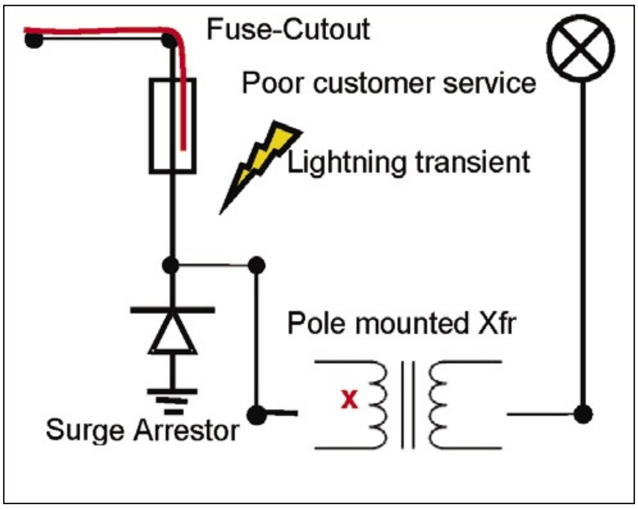

Fig. 4b: Circuit diagram of configuration as per Fig. 4a.

Lightning - the major cause of damage

Fig. 3 summarises the different causes of pole mounted transformer losses in South Africa. Lightning is said to be the biggest cause of transformer damage in South Africa, directly accountable for 65% of all transformer losses, whilst 25% are said also to be indirectly linked to lightning stress on the windings of transformers. This is why, on a perfect sunny day, a transformer may unexpectantly expire. The remaining 10% of failures is shared between human and animal interference, such as overloading, connection problems, birds' nests, etc.

Lightning density

Ground flash density is a measurement of the number of lightning strikes to ground per km^2, averaged over a year. Ground flash density differs from region to region. South Africa has some of the highest lightning densities in the world. The North West Province, Gauteng, Polokwane and Limpopo regions have high lightning densities of around 7 - 10 flashes/km^2/year. Natal has the highest, reaching the maximum of 14 flashes/km^2/year. The Southern Cape region experiences less lightning activity. It is known that about 25% of lightning strikes are cloud-to-ground, whilst the remaining 75% are either cloud-to-cloud or intra cloud. They are also predominantly negative strokes.

Current methods of distribution transformer protection

The typical distribution transformer protection configuration is shown in Fig. 4a and 4b.

Problems with this configuration include:

- Frequent transformer damage.
- Frequent nuisance blown fuses.
- Poor surge arrestor maintenance.
- Live arrester maintenance is not possible.

This installation works well under normal circumstances, but poorly in the stormy seasons. The position of the fuse in front of the surge arrestor was developed in the early years of surge arrestor development, when ground lead disconnector technology was not advanced, and the surge arrestor was dependant on the fuse to remove it from service when it was spent, thus causing loss of supply to the customer.

The advantage of this configuration is that it may extend surge arrestor maintenance periods, but it still results in a reactive approach to maintenance.

The configurarion requires an outage to do maintenance or replacement of the arrestors, which may take up to an hour in certain circumstances.

Combi-configuration (advanced protection)

The Combi unit is an advanced form of surge protection for distribution transformers in South Africa.

The Combi unit changes the surge arrestor-fuse configuration at the pole-mounted transformer into a parallel connectionas shown in Fig. 5a and 5b, in contrast with the conventional series circuits of Fig. 4a and 4b. The main advantage here is that the surge arrestor is allowed to effectively deal with the lightning surge during overvoltage conduction, without losing any phases due to nuisance fuse blowing. This eliminates voltage stress across the windings of the transformer, and other overhead equipment, and enhances performance.

Features

The surge arrestor positioned in the Combi unit is critical to the unit's operation, and once the surge arrestor is spent, it alerts the operator that it needs to be replaced. The transformer Combi unit also has a facility on its pole clamp for spare arrestors which can be replaced on the spot.

Electrical utilities experience fewer transformer losses and a reduction in outages where these Combi units are installed, as the maintenance procedure for arrestors is simplified and made more effective (live line arrestor replacement by link stick).

The customer experiences a much better quality of supply and operators are not exposed to dangerous situations. The Combi unit operates on distribution lines ranging from 3 kV up to 33 kV, and provides electrical utilities with a solution to high rates of transformer loss.

The main advantages of the Combi configuration are :

- It improves the configuration of fuse and surge arrestor.
- It makes live-line maintenance possible for the surge arrestor and fuse.
- It gives a unique surge arrestor alert that informs the utility when the surge arrestor is spent.
- It makes it possible to change both surge arrestor and fuse from the ground.
- It can reduce transformer failures significantly.
- It eliminates nuisance call-outs.
- It is convenient and easy to maintain.
- There is no customer outage for maintenance.
- It enhances safety during maintenance.

Contact Kevin Risi, Live Line Technology, Tel 018 464-1457, kevin.risi@gmail.com ❖

Fig. 5a: Unique Arrestor alert.

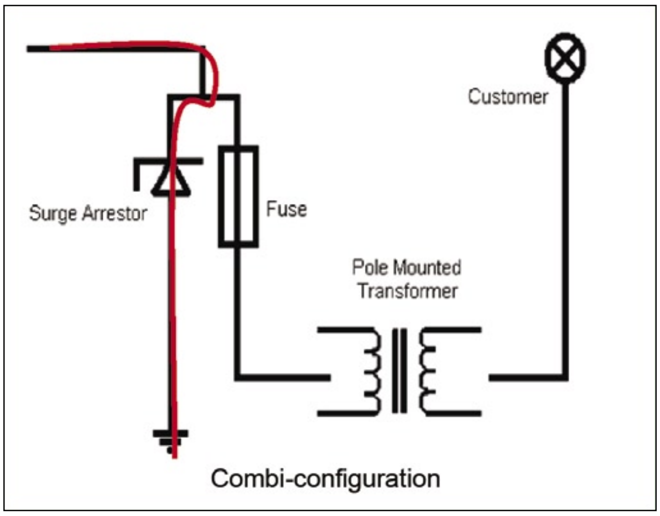

Fig. 5b: The combi-configuration, where fuse and arrester can be replaced with link stick from the ground.