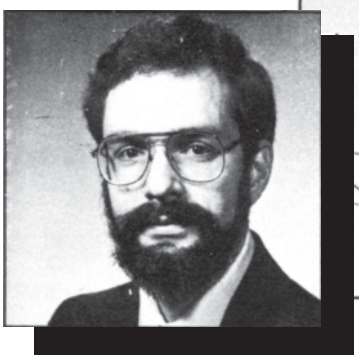
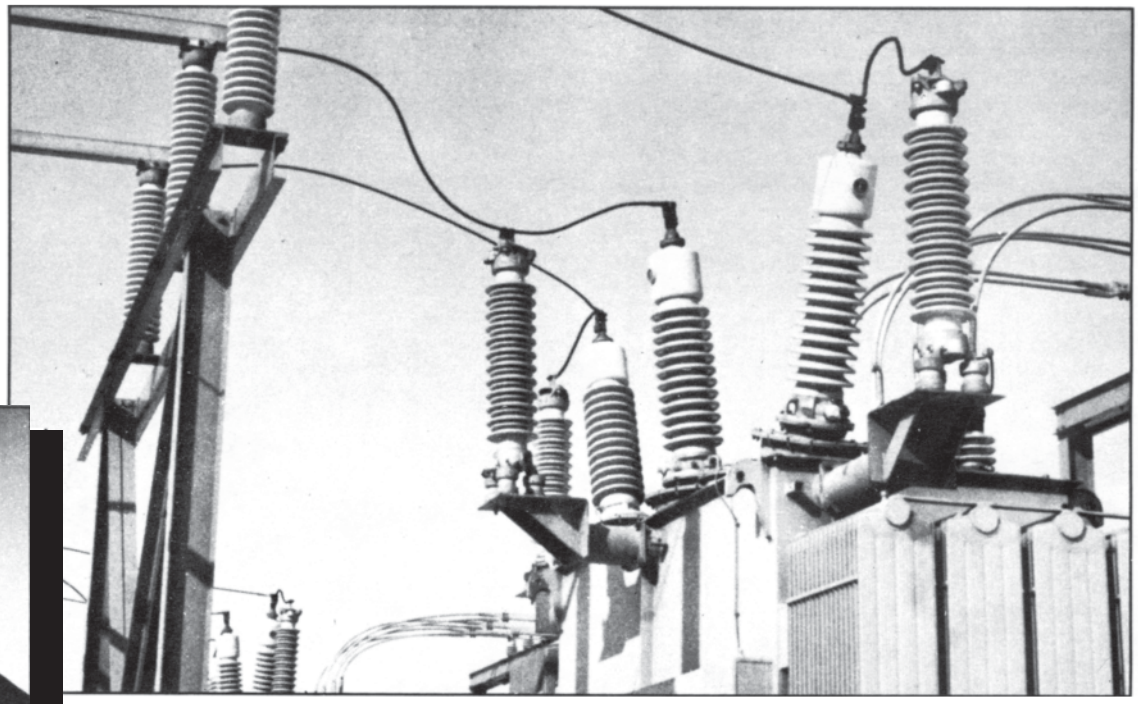
# MOV Arresters Limit Overvoltage on 138 kV Underground

**Roy W. Alexander**





*High side bushings protected by 108 kV rated arresters on a Pennsylvania Power & Light Company 138-12 kV transformer.*

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Pennsylvania Power & Light, located in Allentown, is a major utility which covers most of the eastern half of Pennsylvania, including such cities as Harrisburg, Bethlehem and Scranton. The investor owned system serves over one million customers through 1,312 circuit miles of transmission 230 kV and above. The PP & L network includes 12 major power stations and 350 distribution substations.

The downtown Allentown area is served by a double circuit 138 kV line feeding distribution substations having delta-wye transformers paralleled on the secondary side. The intra-city portions of the 138 kV system are underground solid dielectric cable.

The parallel secondary on .he distribution transformers (138-12 kV} gives rise to a backfeed condition during phase-to-ground faults. Consider this case: a persistent phase-to-ground fault (cable failure, etc.) on either of the circuits feeding the Allentown area will result in backfeeding from the unfaulted circuit through the parallel connected secondaries of the area supply transformers. The backfeeding occurs when the 138 kV source breakers trip to clear the fault. Thus, the circuit is backfed through the 138-12 kV transformers with a delta high side winding.

The phase-to-ground fault puts a ground on one corner of the delta. This results in a phase-to-ground voltage equal to or greater than the phase-to-phase voltage. This overvoltage is aggravated by the capacitive voltage rise (caused by cable capacitance) across the relatively high source impedance of the two back-to-back transformers.

Overvoltages were calculated to exceed two per unit steady state. The overvoltage is preceded by a 3 p.u. transient generated when the 138 kV source breakers clear the faulted line.

The conventional relaying applied to this system allows this backfeed situation to exist for about two seconds. The initially used conventional arresters Silicon Carbide had to be sized large enough to withstand this two-per-unit 60 Hertz voltage without sparkover. This resulted in what became an unacceptably high overvoltage on the solid dielectric cable (2.1 p.u.). At least one cable fault was directly attributed to this overvoltage, and several others were aggravated by it.

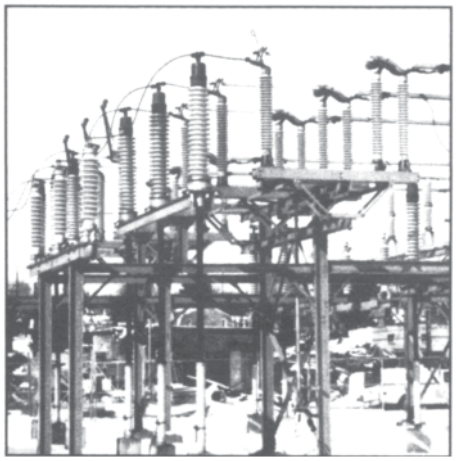
An obvious but not operationally acceptable solution is to avoid paralleling the 12 kV (load ) side of the transformers (i.e., use a break before-make throwover scheme). Two solutions were considered—one to use grounding transformers permanently connected to the 138 kV lines to stabilize the neutral during the backfeed condition (limits overvoltage to 1.3 p.u. for two seconds}. This, although feasible, would be cumbersome and expensive ($1.8 million).

A more innovative approach is to use gapless Metal-Oxide (MOV) arresters operating in concert to control the magnitude of the backfeed overvoltage. However, the power dissipation required was excessive.

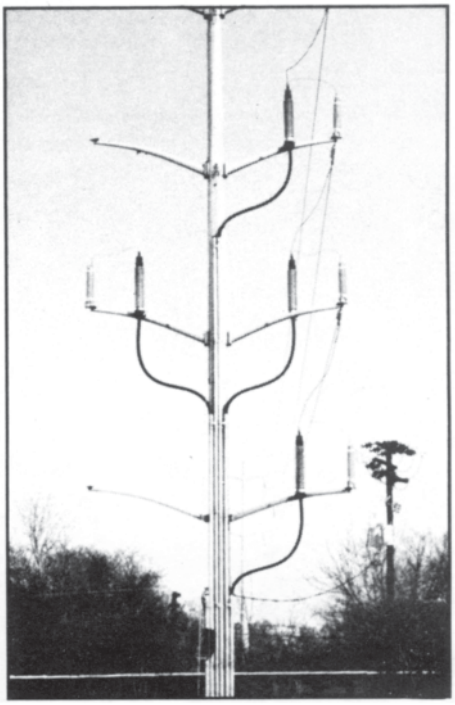
The final solution was to employ high-speed relaying which would clear the backfeed condition in two-tenths of a second along with specially matched, parallel, 108 kV duty-cycle voltage rated MOV arresters to limit the backfeed overvoltage. This solution did not require any additional arrester locations.

In essence, we replaced one-for-one, all conventional arresters on these two 138 kV circuits with specially matched MOV-type arresters. A total of 39 arresters were replaced, five sets on one circuit and eight sets on the other circuit. A special test was conducted by the supplier to ensure the arresters would be matched in the 10-50 amp discharge region of interest for this application.

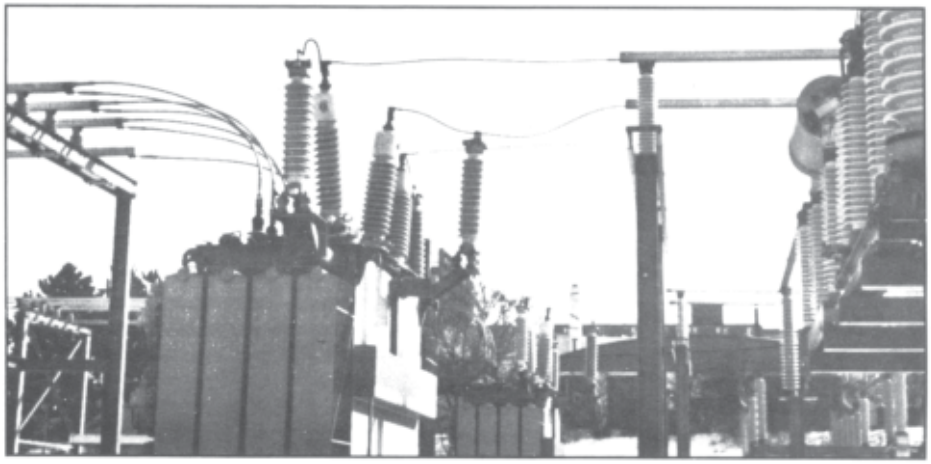
The parallel arrester improved relaying solution limits the back feed overvoltage to 1.6 p.u. for 0.2 seconds and ha a cost of $260,000 ($1.5 million less than the grounding transformer method).



*These specially matched single column arresters in parallel arrangement were selected because the calculated overvoltage would require use of higher voltage conventional arresters offering less protection.*



*138 kV deadend structure with cable termination for substation underground cable entrance. (Note spare cable.)*



*Pennsylvania Power & Light made arrester conversions to MOV to control the backfeed overvoltage on a 138 kV system.*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