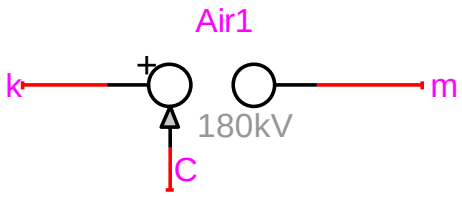
Air gap



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1 Available versions

This device is available in both 1-phase and 3-phase versions. The 3-phase version is the equivalent of 3 independent 1-phase devices with separate data.

1.1 When changing phases

It is allowed to switch from 1-phase to 3-phase or from 3-phase to 1-phase. The user must verify data and scope requests according to requirements. If the device becomes 3-phase from 1-phase without opening and changing its data, the initial 1-phase data is propagated to all phases. If the device becomes 1-phase after being 3-phase without opening and changing its data, the phase-a data is retained.

2 Description

A spark gap is used to protect station equipment by limiting overvoltages in the network. The limitation takes place through creation of an arc and a short-circuit to earth. When the overvoltage at the spark gap terminals exceeds the dielectric strength of air between its horns, the air inonizes and starts to conduct. Ionization conditions depend on several factors, the major ones of which are the form and polarity of the incident voltage wave and the shape of the spark gap. The model of this device is limited to the representation of the behavior of spark gaps in air against fast front waves.
One of the most suitable methods for the evaluation of the moment and level of arcing of spark gaps after a lightning strike, is the integral method. The insulation is modeled by:

$$\int_{t_0}^{t} \left[\left| v_{gap}(t) \right| - V_0 \right]^K dt \geq D \qquad (1)$$

Flashover occurs when the above integral becomes greater or equal to D. t_0 is the time-point from which v_{gap} became greater than V_0. When the voltage v_{gap} goes below V_0 the integral is reset. The gap is an ideal open

switch before flashover and becomes an ideal closed switch after flashover. The gap stays closed after flashover until the control signal C becomes greater than 0, in which case it will reset (open) the gap.

More information on this model can be found in [1]-[3]. The integral law enables calculating the moment t_a and the level U_a of arcing whatever the shape of the wave, notably with standard $1.2/50\mu s$ waves. Such characteristics are available through laboratory tests. Plotting the results of $U_a - t_a$ leads to a nebula of points of roughly hyperbolic envelopes. This characteristic is called "voltage-time characteristic" of the spark gap. Using three pairs of points allows to approximate the parameters of equation (1) through the numerical solution of a set of three integral equations.
This procedure has been used in [3] on insulator strings fitted with spark gaps set between 15 and 80 cm. The calculated results are given below:

Spacing of the gaps in m	K	V_0 (kV)	D
0.8	0.92	343	1.4e-01
0.71	0.92	311	1.3e-01
0.61	0.93	276	1.1e-01
0.4	0.93	205	6.9e-02
0.35	0.93	188	5.6e-02
0.28	0.92	167	3.7e-02

2.1 Parameters and rules

The parameters from the data tab are:

- V_0 is the minimum voltage of equation (1).
- K is the exponent of equation (1).
- D is the level parameter of equation (1).

This device can be 1-phase or 3-phase. It is not allowed to delete any pins. It has zero resistance when closed and infinite resistance when open. It is allowed to connect several gaps in parallel if they do not conduct at the same time. If simultaneous conduction occurs mathematically impossible conditions may result and EMTP *tries* to solve it by inserting artificial resistances.

3 Netlist format

```
_AG;Air1;3;3;k,m,C,
180kV,1,0.0384,?v,?i,?p,>v,>i,>p,>S
```

Field	Description
_AG	Part name
Air1	Instance name, any name.
3	Total number of pins
3	Number of pins given in this data section
k	Signal name connected to k-pin, any name
m	Signal name connected to m-pin, any name
C	Signal name connected to the control pin, any name
V_0	Model parameter.
K	Model parameter.
D	Model parameter.
?v, ?i, ?p	Optional scope requests
>v, >i, >p, >S	Optional observe requests

In the 3-phase case, EMTPWorks automatically appends the phase characters and creates 3 separate devices each with separate phase data. The control signal is the same for all phases.

The comma separated data fields are saved into ParamsA, ParamsB and ParamsC attributes of this device.

4 Steady-state model and initial conditions

The steady-state model of this device is an infinite resistance.

5 Frequency Scan model

Same as in steady-state.

6 Time-domain model

This device is modeled as a zero resistance when closed and as an infinite resistance when open.

7 References

[1] P. Darviniza, F. Popolansky and E. R. Whitehead: “Lightning protection of UHV transmission lines”, Electra no. 41, July 1975.

[2] D. Vidal, S. Sadovic, R. Soler: “Dossier de spécification d’une maquette de logiciel pour des études statistiques de foudre dans les postes (INCA), D. Vidal, S. Sadovic, R. Soler, HM-77/94/080

[3] M. Rioual : “Short and long air gaps (insulator strings and spark gaps) modelling for lightning studies with EMTP program (EPRI-DCG version 2.0)”, Research project, final report, March 88