TRANSIENT ANALYSIS OF VOLTAGE DIPS IN MV DISTRIBUTION NETWORKS

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Abstract - **In the paper, is reported a probabilistic approach for the determination of the mean expected value of voltage dips and the study of the influence of voltage transients subsequent to a fault on the shape of voltage dips by using ATP . An equivalent circuit of a MV distribution system enclosing power transformer, ingoing and outgoing lines is modelled. The simulations carried out have shown how the transient voltage does not influences the shape of voltage dips.**

Keywords: Voltage dips, Transient, MV network.

I. INTRODUCTION

In the field of the electromagnetic compatibility (EMC) one of the most dangerous conducted disturbances is the voltage dip, it can influence the regular operation of several sensitive loads categories, depending on its amplitude and duration.

As an example, voltage dips can disable electric motors because of the undesirable operating of the protective relay, can determine the shutdown of the gas-discharge lamps, or can cause malfunctions in microprocessor control systems, programmable controllers and induction heating furnaces.

It seems useful to remember that voltage dip is: "A decrease to between 0.1 and 0.9 pu in rms voltage at the power frequency for durations of 0.5 cycle to 1 min. Typical values are 0.1 to 0.9 pu"[1]. If the amplitude of the voltage fall to zero, the disturbance is called short interruption. Voltage dips can influence one or more phases and have generally irregular waveforms.

Voltage dips can have three different types of origins: faults in the public network, faults in the industrial installation itself and switching of a consistent load [2].

In this paper, transient behaviour due to voltage dips which occurs in MV networks with insulated neutral as a consequence of a fault, is analysed. The short-circuit current must be eliminated disconnecting the defective component of the system, by opening the circuit-breaker. Usually the circuit-breaker opens after a delay of few hundred of milliseconds. Between the fault occurring and its elimination the line voltage fall down depending on the amplitude of the short circuit current.

The shape of the consequent dip depends on the characteristics of the electrical system, on the type of fault, on the protective devices and on the mutual position between the faulty section and the measuring instruments. With reference to this kind of conducted disturbances a research is going to be developed, the aim of the research is to determine the average distribution of the amplitude and duration of the voltage dips subsequent to a fault condition.

These disturbances will last short periods of time immediately after the occurring of a fault. The amplitude and the duration of each voltage dip could be more or less influenced from the transient of the phenomena.

The evaluation of this influence is important, it has an heavy part on the choice and set up of network analysis methodology which could be useful to determine the effects of every type of fault on the reliability of the predictive method. The aim of this work is to evaluate the influence of transients on voltage dips; we must take into account that there is little or no literature information.

In the following part is given a synthetic description of the probabilistic method applied to determine the average distribution of voltage dips. The results of the research are reported in order to estimate the influence of the transient on the parameters which characterise it.

The methodology shown is general, since it analyses any type of fault with a systematic approach not dependent on the particular model used to schematise the network. Finally an example of an application is given.

II. PROBABILISTIC APPROACH FOR THE DETERMINATION OF THE MEAN EXPECTED VALUE OF VOLTAGE DIPS

The forecast of the amplitude ΔV of each voltage dip subsequent to a fault condition can be carried out through the application of an analytical model Ψ of the electrical system.

$$\Delta V = \Psi(p,q,c_i,u_g,u_s) \qquad (1)$$

where the meanings of the variables are:

"p" class of fault (transient fault, semipermanent fault, permanent fault);
"q" type of fault (single phase to ground, biphase,...);
"c_i" characteristics of faults (resistance,...);
"u_g" location of the fault;
"u_s" location of the observer.

The correspondent duration ΔT can be estimated depending on the characteristic Π of the protective devices:

$$\Delta T = \Pi(p, q, I_g) \qquad (2)$$

where I_g is the fault current.

The typical protective devices used in a neutral isolated MV network have different operating characteristics, those characteristics depend on the typology of the fault and on the amplitude of the short circuit current.

The protective devices are also associated with automatic reclosing (circuit breaker and recloser) whose operation is related to the class of fault.

The relations (1) and (2) concur to characterise every voltage dip, when is known: the location of the fault that produces it and its characteristics for an overhead line of MV.

The number $n_{p,q}$ of faults and the fault characteristics c_i are random variables, with a probability density function related to the statistic studies done on networks of the same type.

As an example will follow the gauss distribution of the single phase to ground fault (fig.1) and the probability function of the fault resistance (fig.2).

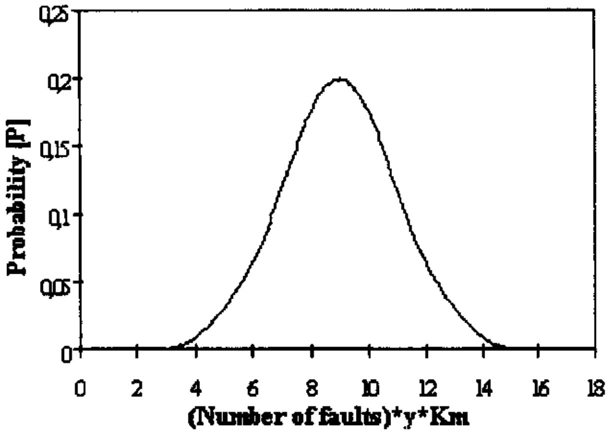

Fig. 1 Probability trend of the number of single phase to ground faults referred to a year and to a line of 100 Km [3]

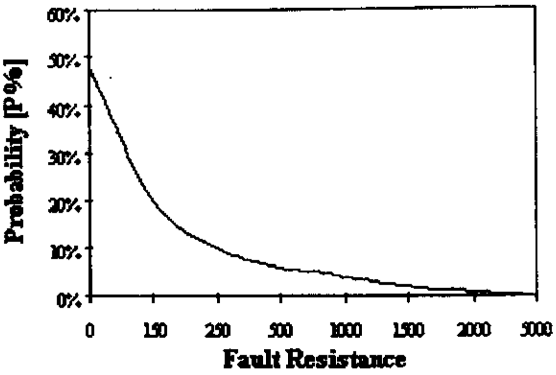

Fig. 2 – Probability trend of single phase to ground fault resistance [3]

The determination in every node of the network of the attended mean distribution of ΔV and ΔT can be done by using Montecarlo method.

The cumulative probability function for a generic random variable "x" is:

$$y = \int_0^x P(x)dx$$

the range of values it could assume varies between 0 and 1 (fig.3).

The implementation of Montecarlo method involves the extraction of a random number "y" with a uniform probability function between 0 and 1. The number "y" is associated to a value of the variable "x" by using the graphic of fig.3. When the number of drawings is very high we find the average distribution of the variable [4].

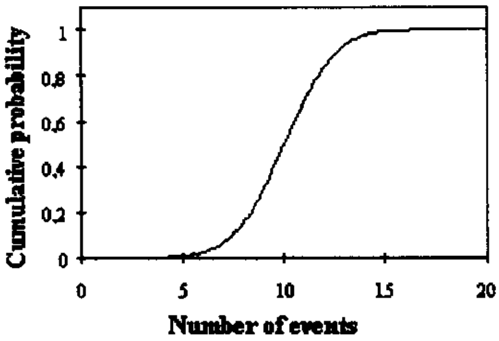

Fig. 3 Density of probability trend of a generic random variable x

III. THE STUDY OF THE INFLUENCE OF VOLTAGE TRANSIENTS SUBSEQUENT TO A FAULT ON THE SHAPE OF VOLTAGE DIPS

The influence of the transient on voltage dips has been analysed on networks of different type and extension; each line of the networks is protected by a different circuit breaker.

The following types of faults have been analysed:

- single phase to ground fault;
- biphase fault;
- three phase fault;

- double single phase to ground fault in two different nodes.

The present study is aimed to value the voltage lowering in a generic node of the network, when a different one is affected by a fault.

Different sequences of events, and various operating of the protective devices, usually used in ungrounded MV networks, have been considered:

a) steady state network – fault at $t = t_1$ – opening of the circuit breaker at $t = t_2$;
b) steady state network – permanent fault at $t = t_1$ – opening of the circuit breaker at $t = t_2$- automatic reclosure at $t = t_3$ – fault not extinguished – permanent re-opening at $t = t_3$;
c) steady state network – transitory fault at t = tl – opening of the circuit breaker at $t = t_2$- automatic reclosure at $t = t_3$ – fault extinguished.

Each component of the network has been modelled in ATP-EMTP code, together with the arc parameters of the circuit breaker [5].

The results obtained seem to show that the transient of the voltage, in a voltage dip, will not influence the amplitude and duration of it; it is possible to see only overvoltages immediately after the occurring of the fault and the operation of the circuit breaker.

In reference to the disturbances analysed a research is under development, it is aimed to determine the attended mean distribution of the amplitude and duration of the voltage dip in each node of the network when a fault will occur.

As consequence of the results illustrated before, the methodology applied in that research will be referred to the steady state part of the phenomena because the transients does not influences the shape of voltage dips.

IV. APPLICATION

The figure 4 shows the scheme of the simulated network, in figg. 5-10 examples of condition a, b and c are reported.

All the results obtained, monitoring the waveform of the voltage calculated in a node not affected by a fault are the followings: the transient calculated subsequent to a fault condition will last about 20 ms (one period), so that before the circuit breaker opens the line voltage reaches the steady state value of the fault condition.

A similar behaviour is observed for the voltage transient subsequent to the opening of the circuit breaker or to its automatic reclosure is shown in figg. 5,6,7,8,9,10.

To validate the results in appendix an expansion of the waveforms of fig. 5, related to two different networks, is reported.

The waveforms of the line voltages calculated for the three phases is dependent on the type of fault and on its location, they are normally affected by high frequency components and by overvoltages whose amplitude is connected to the circuit breaker operations; in all the cases analysed, in the period of time in which the overcurrent lasts after 20 ms from the beginning of the short circuit, the voltage lowering reaches its steady state value.

The application example consists of a network with radial structure. It is constituted of two MV overhead lines outgoing from the same HV/MV substation (150/20 kV/kV); the lines are connected each other through the MV busbars of the substation.

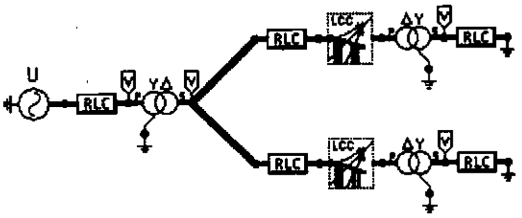

Fig. 4 - An example of the network used for the simulations

In particular the network is composed by (fig. 4): a 150 kV equivalent voltage source, having short circuit power equal to 1500 MVA; a HV/MV substation with a transformer of nominal power equal to 25 MVA; two MV overhead lines which are simulated by employing a distributed parameters model; such lines feed two MV/LV transformers of 250 kVA;

The network is protected by circuit breakers associated with automatic reclosing, typically used in Italian MV networks.

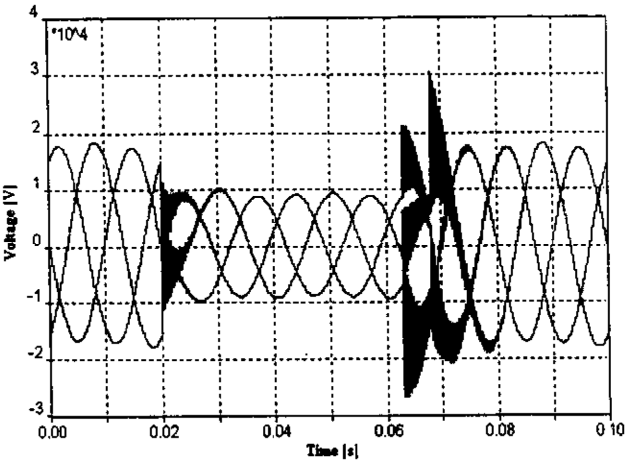

Fig. 5: steady state network – three phase fault at $t = t_1$ – opening of the circuit breaker at $t = t_2$;

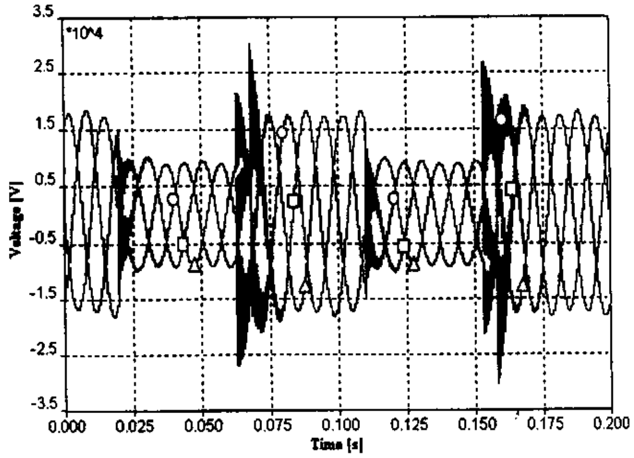

Fig. 6: steady state network – permanent three phase fault at $t = t_1$ – opening of the circuit breaker at $t = t_2$- automatic reclosure at $t = t_3$ – fault not extinguished – permanent re-opening at $t = t_3$

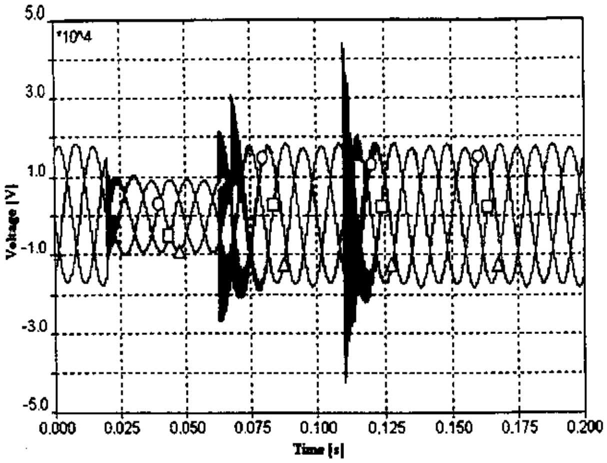

Fig.7: steady state network – three phase transitory fault at t = t_1 – opening of the circuit breaker at t = t_2- automatic reclosure at t = t_3 – fault extinguished

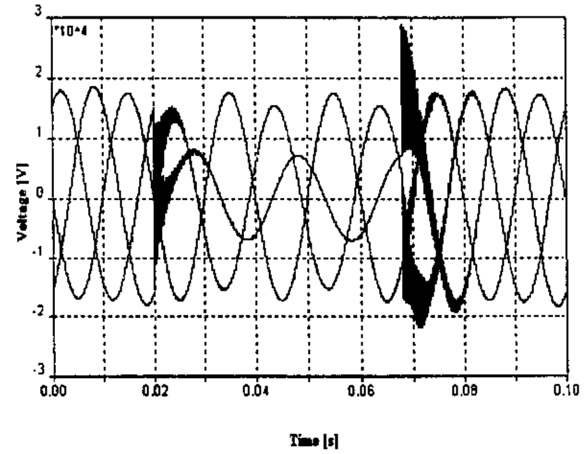

Fig. 8: steady state network – biphase fault at t = t_1 opening of the circuit breaker at t = t_2.

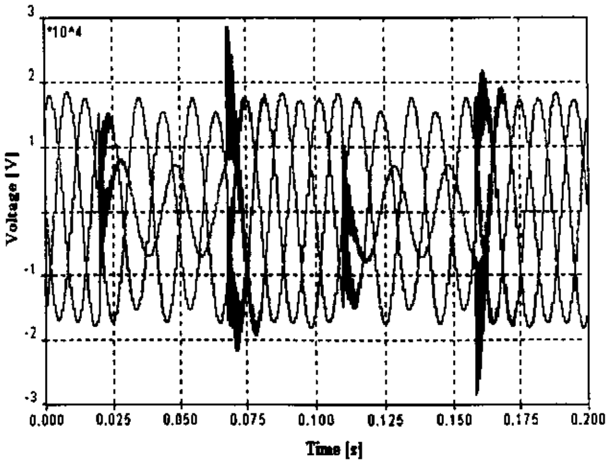

Fig. 9: steady state network – permanent biphase fault at t = t_1 – opening of the circuit breaker at t = t_2- automatic reclosure at t = t_3 – fault not extinguished – permanent re-opening at t = t_3

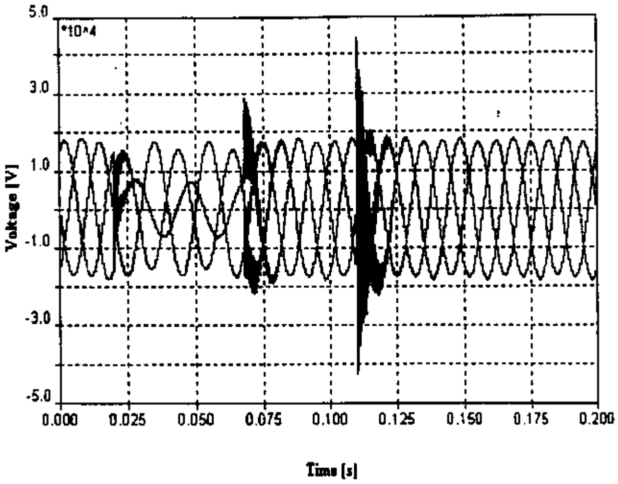

Fig. 10: steady state network –transitory biphase fault at t = t_1 – opening of the circuit breaker at t = t_2- automatic reclosure at t = t_3 – fault extinguished

V. CONCLUSIONS

Transient behaviour due to voltage dips which occurs in MV networks with insulated neutral as a consequence of a fault condition has been analysed, with reference to a typical radial configuration of the Italian electric power MV distribution network. Various kind of faults on a overhead MV line have been considered. The simulations carried out seem to show how the voltage transient does not influences the shape of voltage dips, because it lasts only few milliseconds.

VI. REFERENCES

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VII. APPENDIX

The network simulated is a 20KV overhead distribution line of 3 Km, it is typically used to distribute energy in rural zones.

The magnitude and duration of the high frequency transient recovery voltages are consequence of the network structure, the figure below shows an expansion of the waveform of fig. 5.

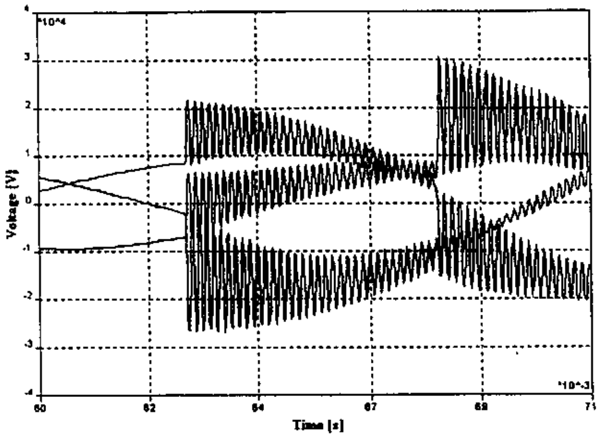

Fig. 11 – Expansion of the plot of fig. 5

In order to verify the authenticity of the plot shown, a similar network with an extended line of 20 Km length was simulated. The new overhead line is longer than the first, so the inductance and capacitance, associated to the network, are higher in values so the oscillating frequencies are lower.

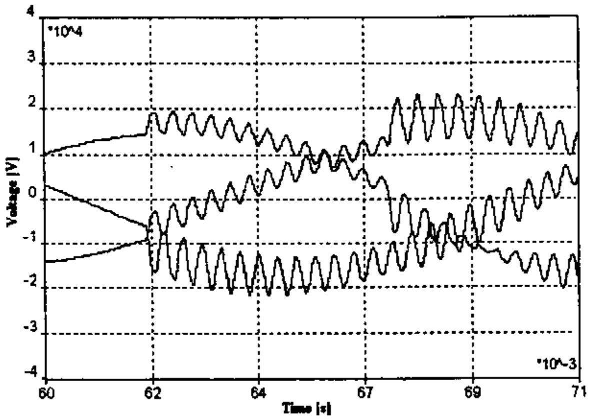

Fig. 12 – Transient phenomenon in a overhead line of 20 Km length