Review of DC arc fault detection

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Abstract.

DC electric system related to power is used in many system across the globe. The development related to technology of renewable energy apart from the application in the field of power electronics it was observed that the DC network for the distribution of the power used so that there shall be proper integration of renewable resources. There are different advantages of this system but the disadvantage includes DC arc faults. DC arc faults occurred when high voltage DC buses are used in the electrical components. There are different accidents occurred because of the DC arc faults introduction in the different situations. The present work consists of the review on the different methods to be used for the detection of the DC arc faults and devices can be used for the detecting the location of it. Several authors used methods related to AI, experimental test-bed was prepared, analytical and simulations of the models are also carried out.

Keywords: DC, arc, fault and voltage

1. INTRODUCTION

When the arc which was not intended considered to be the fault in arc and it is generally created when current flow through some path which was not planned and this lead to a condition of fire. The diagnosis of the fault is to be carried out and the purpose behind this is to isolate faults especially for the system which are defective. But this task is considered to be of extraordinary skill. Therefore the system of automation in the diagnosis is very important [1]. The MATLAB power system Blockset was used along with Arc Model Blockset, this is one of the library useful to make the models related to arc.

The validation is also carried out is the study while the program is made to study arc and its interaction with circuit [2]. The detection of the fault was proposed and this techniques is used when there is processing in terms of the fundamental voltage which are synchronized. Here the utilization of the current phasors for the case of arcing apart from the faults which are permanent. [3]. The methodology was adopted for the detection of faults which are single phase, in particular when the resistance in the fault is varied up to 15 kΩ, distribution system adopted was radial. This method is obtained through program of ATP where the realization of arc model is considered the representation of arc which was universal [5].

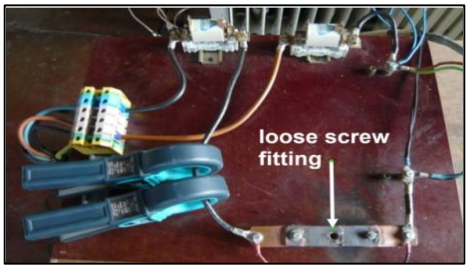

Fig.1.1. Measurement set-up arranged for series arc fault

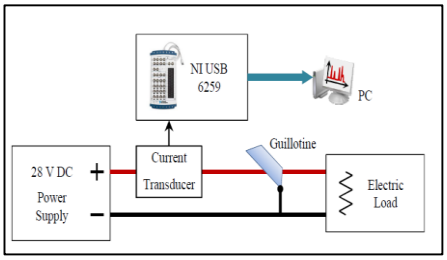

Fig. 2.1. Experimental set-up used in the fault detection [10]

2. TWO ARC FAULTS (SERIES AND PARALLEL)

It was observed that generally two type of the faults in arc generated, especially in case of switchgear having low voltage. Parallel and series arc faults are two types of arc which is responsible for the damages to system of switchgear [6]. The performance of the device was studied in the experiments [7] for the test. The investigation of PV system and behaviour of it was carried out for the both type of faults in the arc. [8].

TABLE I. SUMMARY FOR DIFFERENT METHODS USED FOR DETECTION OF AN ARC FAULTS

Reference	Year	Type of Analysis	Findings
[5]	2007	Discrete Wavelet Transform	Enhancement in Arc reignitions
[6]	2010	Fourier analysis	Detection of fault in arc when the load current is measured in switchgear.
[11]	2013	Analytical	Analytical expressions depending upon different parameters are obtained
[12]	2014	Fast Fourier Transform and Wavelet decomposition	Wavelet transformation method has more rapid detection system
[13]	2017	Wavelet transform and Convolutional Neural Network	The method was useful under different conditions of the fault and factors of interference
[14]	2019	Random forest method, wavelet packet transform	Random forest method gave higher performance for the detection of arc fault
[15]	2021	Frequency spectral analysis	Considered indicators useful to detect presence of an arc, integration of algorithm to be used for detecting arc fault
[16]	2021	Artificial neural network, fuzzy system	Average performance for the detection of arc faults found to be same in both analysis methods.

To differentiate the parallel arc fault and series arc faults the alternative method was studied. The suppression of arc faults was also studied, there was possibility of de energization in case of series arc faults and parallel arc faults through some methods [9]. The identification of arc is carried out through innovative approach when the two different parameters are evaluated. Parameters included current spikes with concurrency rate apart from specific energy [10].

3. SERIES ARC FAULT DETECTION

To detect the arc series fault the PV system was studied where the use of circuit interrupters used as the protection purposes. The DC switching with fast acting was used in the system of protection. The current solution having discrete frame differentiation had been used in the

detection system [17- 19]. The heuristic model was used since it was easy for the simulation of arc for the kind of voltage level as well as different level of the current. The noise intensity of the arc for the frequency band of below 50 kHz increases considerably for the case of faulting of the arc [20]. The nonlinear loads and complex loads in terms of the load of power electronics considered and analysis was carried out. For the case of detecting arc faults different parameters of the current including average, median, variance, and distance between minimum and maximum values analysed [21]. The electric arc was studied for the calculation of transient resistance especially for the case of short circuits, the mathematical expressions are derived. The simulation in the MATLAB was also carried out,[22]. The reduction of the effect having hot spot and the detection of DC arc fault was studied through various research papers [23]. The review was carried out on the location detection and detection of an arc fault for the case of DC photovoltaic grid. The simulation models had been studied for the results in terms of the different analysis like Fourier Transform on the arc faults [24]. The review was carried out on the detection of the faults using AI methods; the diagnosis was also carried out in the PV system. The AI considered being useful tool for the different application including solar [25]. The different algorithms were studied and then classified in to groups i.e. heuristic and classic methods. Different algorithms related to these methods were studied in detail[26]-[27].

4. EXPERIMENTAL DATA

The loop current was captured with the help of current transformer having frequency of 600 Hz, this was helpful for filtering disturbances having low frequency especially for the case of dust and changes in the weather. The input was given in terms of the current signal with 20 kHz rate of sampling. Photovoltaic emulator was connected in the series with arc generator apart from single 1.5 kW phase inverter-Sunny Boy [28]. An inverter generally have the switching device with higher frequency i.e. in the range of 10-20 kHz. The analysis of the arc fault detection system considered when the current signal having 48.33-93.99 kHz frequency modules had been extracted [29]. The AC arc fault experimental system consisted AC supply of power, load box, resistance, contactor, sensor and generator of arc with the standard UL1699. These different components played a vital role for the system [30]. The experimental set-up consisted power supply with 10 kW keysight, opal 4510, generator of an arc, power electronic circuit. Opal 4510 used for the controlling buck converters and resitors, the constant power loads connected in parallel with 14A- input current, 200V-output voltage [31].

5. SIMULATION

For the purpose of simulation there are different models which can be used. The empirical models includes Nottingham arc model, Hall arc model, Myer arc model, Viicheck model, stokes model, Oppenlander arc model, Paukert arc model and modified Paukert arc model [32]. The simulation of the electric arc can be carried out in software tools and these are available in the software. For the case of the black box models the simulation was carried out in the MATLAB Simulink. When this tools used then the analysis carried out for system of power in the time domain, differential equations were solved which helped for the understanding of component behaviour [33]. The Simulink used for the arc model consists of the block named ‘Hit crossing’, this used for detection for the case of current as

input cross the value of 0. The adjustment of the stepsize carried out so that the simulation get the cross value. 'Step' block in terms of the Simulink used for controlling separation of contact in case of breaker of circuit [2]. The simulation of the arc models is carried out in the MATLAB software for the arc current with different units i.e. 12.5 kA to 40 kA, in this tool model of Hochrainer and Cassie was used. The results obtained in the Simulink had been compared with the experimental tests carried out on the short circuit with same arc current [34]. For studying variation of arc faults in the PV components, arc current with changes in the long-time are collected through the experimental set-up. Habedank arc model was considered for the case of simulation of U-I characteristics related to model of arc. The interaction was studied for the series arc model and the algorithm related to Maximum Power Point tracking [35].

6. ALGORITHM

Support vector machine is considered to be best algorithm for the supervised learning purposes. The important thing behind the support vector machine part is the creation of hyperplane having the highest margin that is available in between two classes adjacent to each other. This is helpful for bounding the error which is generalized for the case of model [36]. Heuristic search method used for investigating approximate value. Due to this the arc modelling was carried out in precise way [37]. The discrete wavelet transform was used apart from the deep neural network so that the detection of arc faults can be improved with accuracy. While calculating the wavelet transform, Mallat algorithm theory was used. When the approximation considered then sequence for the closed loop subspace used. The wavelet function i.e. Sym8 was used for performing different five levels of the decomposition of wavelet for the case of sampling signals of current [38]. The neural network was dependent on the gradient evidence which was related to the error function. It was observed that the BP neural network is not useful in the case of initial value was not considered appropriately [39]. Deep convolutional neural network is considered to be unusual kind of the neural network. This considered having very good performance in the field of vision for computer and processing of image [40] .AFD algorithm was used and it was found that to get accurate AFD in the Intel Arc considered to be have impact for the interpreting correctly LL outputs. When the fault detection needed to be carried which dependent on MLT where the learning algorithm have been used and trained. This consisted experimental data for learning different relation for the parameters of input and output. Training was given to the data obtained from the model having predicted PV [41].

7. CONCLUSIONS

There is tremendous growth in the economic level and this leads to the increase in the electrification for commercial and residential use. This also leads to the increase in the electricity loads and ultimately this becomes the reason for the potential hazards. The use of DC in electrical components considered to be the development in the field of power electronics as well as the renewable resources. When the DC network is to be used then the protection should be the key part of the network. From the various research papers it was observed that the DC arc faults are increased because of higher DC voltage, difficult to

detect arc faults. The possibility in the tripping when the noises are created in the power electronic devices.

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