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Arc Flash Hazard in Distribution System with Distributed Generation

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Abstract

This work presents the arc flash hazard assessment in distribution system including Distributed Generations (DGs). The results demonstrate the impacts of DGs on the incident energy released from arc due to short circuits. The fault current contribution from DGs decreases the arcing time consequently decreases the incident energy. This situation causes the underestimated arc flash hazard. Finally, the circumstances and the parameters should be aware for arc flash assessments are discussed.

Keywords: Arc Flash; Distributed Generation; Overcurrent; Plasma; Protection

1. Introduction

Arc occurs when a current passes through air between conductors. The high temperature from arcing can reach 20,000-50,000 K [1]. It causes serious burn of skin and fire. Arc do not only emits heat, but also high pressure particularly for arc in an enclosure. This can cause explosion of switch gear enclosure if the pressure cannot be vented out appropriately. The standards to deal with arc flash assessment are NFPA 70E and IEEE 1584. In the standards, the severity is described in term of incident energy released form arc source. Three phase faults occurred in system are considered to be the source of the highest arc flash hazard [2], [3]. However, the present of DGs changes short circuit

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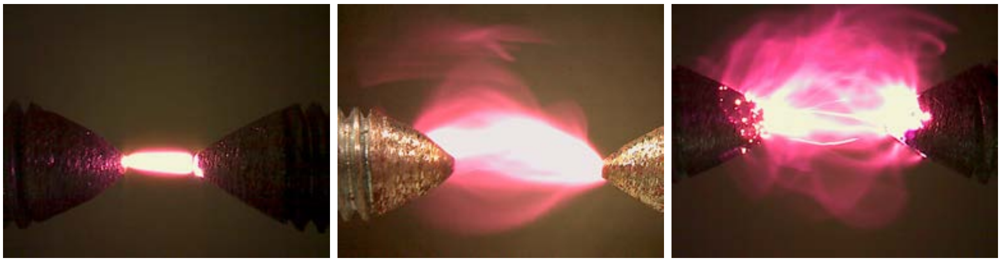
condition of system due to their contribution of fault current. They do not only cause the protective device malfunction, but also the arc flash [4].

This paper presents how DGs impact on arc flash assessment. The studies were carried out on IEEE 34 nodes test system [5]. The protective devices and DGs are deliberately modeled using power system simulation software, DIgSILENT. The arc flash incident energy are calculated and compared with one from the system including DGs. The circumstances and parameters should be concerned are presented and discussed.

2. Arc Flash Phenomena

Fig. 1 demonstrates atmospheric air arc flash phenomena observed from the reduced-scale laboratory test. In this work, the direct current voltage of 10 kVdc was supplied to metal electrode tips. The gap between tips was ~ 4 mm, causing the average field strength around ~25 kV/cm that is close to typical breakdown voltage of air (~3x104 V /cm). However, the edge of electrodes concentrate localized electric field up to ~105 V/cm, altering the air-insulator into the conductive path, causing arc flash (Fig 1a). Therefore, gas around electrode is reaching the very high temperature up to several thousand degrees Kelvin known as thermal plasma (Fig 1b: with pink glow color). If the protection system such as circuit breaker does not operate properly, the intense heat from the arc will extend damaged and heated area, resulting in arc flash explosion in a blast (Fig 1c). Therefore, the arc flash hazard assessment has been one of a crucial subject to increase the level of safety for the electrical worker and environment.



(a) (b) (c)

Fig. 1. Arc flash processes. Development of (a) arc flash and (b) thermal plasma between terminals. (c) An intense arc flash explosion.

3. Arc Flash Hazard Assessment

In this section, the brief procedures of assessments based on IEEE 1584-2002 are demonstrated. The arcing current (I_a) for system voltage under 1 kV can be determined using three phase bolted fault current (I_{bf}) as Eq. 1.

$$\log I_a = K + 0.662\log I_{bf} + 0.0966V + 0.000526G + 0.5588V\log I_{bf} - 0.00304\log I_{bf} \quad (1)$$

where K = -0.153 for arc in open air and -0.097 for arc in an enclosure, G is the gap between conductors and V is system voltage. The incident energy (E) for a specific working distance (D) is as follow.

$$E = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D^x}\right) \quad (2)$$

where C_f =1 for system voltage above 1 kV and 1.5 for voltage below 1 kV, t is arcing time, x is the distance exponent and E_n is normalized incident energy which is as a function of I_a as express in Eq. 3.

$$\log E_n = K_1 + K_2 + 1.081\log I_a + 0.0011G \quad (3)$$