Rethinking stepdown transformers whitepaper

Reduce arc flash hazards on stepdown transformer applications

An explosive arc fault happens when someone or something comes into contact with live conductors and creates a fault between phases. The light and heat produced from the explosion is known as an arc flash, and it can cause substantial damage to electrical system equipment and catastrophic injury or death to service personnel. To reduce arc flash risk to operators and maintenance personnel, new system design methods are being implemented.

One simple but highly effective method consists of relocating the main breaker of a low-voltage panelboard into the enclosure of the stepdown, dry-type ventilated transformer that feeds it. Simply relocating the secondary main breaker to the transformer drastically reduces the amount of available incident energy at the secondary panelboard. This greatly increases the safety of interacting with the secondary panelboard.

Secondary protection becomes a primary consideration

Interestingly, arc flash incident energy calculations on even small kVA stepdown transformers are causing designers to rethink the optimum transformer and secondary panelboard protection schemes. A simple strategy of relocating the secondary protection can drastically reduce arc flash incident energy and significantly increase safety.

It is no surprise to engineers who have performed arc flash incident energy calculations that the secondary of transformers is always an area with high incident energy levels. Arcing faults are much lower in magnitude than bolted faults. And, when they occur on the transformer secondary, these low-magnitude currents must reflect back to the transformer primary (further reducing the magnitude by the turns ratio of the transformer) to eventually be cleared by the primary protective device.

The resulting high incident energy levels extend from the transformer secondary to the downstream secondary equipment. These high incident energy levels on transformer secondaries occur on substation-type, padmount-type and even the smaller dry-type distribution type transformers. However, prior to IEEE® 1584 update in 2018, 125 kVA and smaller transformers with secondary voltages of 240 VAC or less were excluded from incident energy calculations. Now, after significant additional IEEE field testing, it was determined sustained arcing events are possible at or below this kVA size and voltage level. Thus, the exclusion was eliminated from the IEEE 1584 standard.

Bigger transformers, bigger challenges

Even today, NFPA 70E® 2021 Arc Flash PPE Category Method 130.7 (C)(15) (a) allows for panelboards 240 volt and below with 25 kA of available fault current or less to be serviced in PPE with Category 1/arc flash boundary of 19 inches. However, this level PPE is inconsistent with the incident energy analysis calculations.

> Even a 75 kVA distribution dry-type transformer, with a typical impedance value (3.51%Z), will have incident energy of > 11 cal/cm2 at the secondary panel!

And, as transformer size increases, so does the incident energy level! It should also be noted that this incident energy value is consistent through the full range of available fault currents on the primary side of the transformer, from 10–65 kA.

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The simple solution

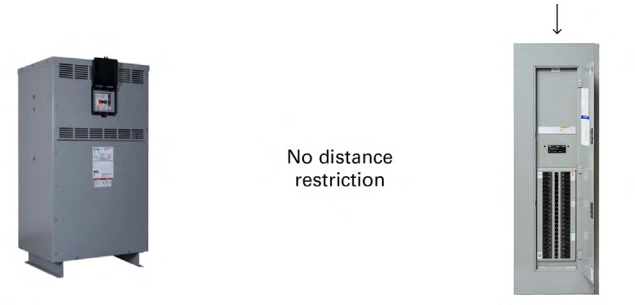
Traditional electrical system design normally places the transformer secondary breaker as the main breaker in a lighting and appliance panelboard located within 10 feet of cable length of the transformer secondary. This means that nearly the same incident energy level on the transformer secondary is also available at the panelboard. For our 75 kVA example, the panelboard would be required to be marked with an incident energy level of 11.60 cal/cm^2, requiring those interacting with this panelboard to wear PPE Category 3. Transformers 150–300 kVA require Category 4 PPE. Above 300 kVA would likely be > 40 cal/cm^2, which would be prohibited from interaction while energized.

Main Breaker Panelboard

Category	cal/cm^2
45 kVA Panel	6.67
75 kVA Panel	11.60
112.5 kVA Panel	14.80
150 kVA Panel	26.38
225 kVA Panel	32.39
300 kVA Panel	42.07

Panelboard Fed from breaker integrated transformer (BIT)

Category	cal/cm^2
45 kVA Panel	0.10
75 kVA Panel	0.17
112.5 kVA Panel	0.38
150 kVA Panel	0.65
225 kVA Panel	0.67
300 kVA Panel	1.05



Without even changing the electrical system one-line, designers have the opportunity to reduce the incident energy of the panelboard to less than 1 cal/cm^2. How? By simply moving the secondary breaker from the panelboard and integrating it into the transformer enclosure itself as can be done with Eaton's BIT (Breaker Integrated Transformer) product. With this approach, when the secondary breaker is properly sized, it will operate in 1–3 cycles (16–50 msec). For our 75 kVA example, incident energy is reduced from 11.60 cal/cm^2 to 0.17 cal/cm^2.

Eaton Breaker Integrated Transformer (BIT)

Eaton's Breaker Integrated Transformer (BIT) is a standard, fully tested product. It integrates the required secondary breaker into the distribution transformer enclosure without utilizing any additional floor space vs. traditional transformer or any additional labor for the installing contractor. The BIT solution provides a simple, cost-effective opportunity to create a much safer working environment for those who interact with panelboards.

In addition to enhancing workplace safety, Eaton's BIT satisfies NEC® Articles 240.4 (F) & 240.21(C), which mandate the location of secondary overcurrent protection and provide the designer additional freedom to locate the panelboard outside of the normal 10-foot cable length limit. Other approaches that utilize panelboard line-side boots or barriers only protect from shock hazards and/or reduce the likelihood of line side arcing. They do not actually reduce the arc flash incident energy available at the secondary panel. Secondary enclosed breakers or fusible switches that are separate from the secondary panel can be used for similar arc incident energy reduction, but require additional installation labor and wall space.

Safety matters

By simply rethinking the placement of the transformer secondary protection, electrical safety at secondary lighting and appliance panels can be greatly enhanced. Eaton's BIT is the simplest, most cost-effective approach to improving safety. It provides drastically reduced incident energy without increasing footprint, wall space or installation labor.

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