Recommended Maximum Branch Circuit Lengths for Isolated Power Systems

“Conduit runs for isolated branch circuits should be as short and direct as possible to minimize accumulated leakage current in the circuit conductors. Generally, 400-450 feet is the maximum recommended cumulative length for all branch conductors from a single transformer. Avoid unnecessary bends and junctions.”

Excerpt from PG LifeLink Isolated Power System Design & Installation Guidelines

As with most guidelines for design and installation of isolated power systems, the underlying goal is to minimize the accumulated leakage current of the installed system in order to ensure safe and trouble-free operation. Leakage current is dependent on two factors: insulation resistance and capacitive reactance between each of the two energized conductors (L1 & L2) and ground. Combined, these two factors define the system ground impedance, which has an inverse relationship to ground leakage current. As impedance decreases, leakage increases. Therefore, our desire is to ensure the effective ground impedance is as high as possible for installed systems. In accordance with NFPA 99 section 6.3.2.6.2, newly installed systems must be tested to verify a minimum ground impedance of 200,000 ohms. For a 120 VAC system, this translates to 0.6 mA (or 600 µA) of leakage current (a 240 VAC system can have up to 1.2 mA as calculated using Ohm’s Law: \( V = I \times Z \)).

In order to fulfill this requirement, it is useful to limit the amount of branch circuit wire connected to the panel. The use of wire insulation with an insulation resistance of greater than 20,000 MΩ-ft. and a dielectric constant of 3.5 or less is highly recommended. Type XHHW, XHHW-2, as well as certain other cross-linked polyethylene (XPLE) insulations types are suitable for this application. On average, you can expect to measure approximately 1 µA of leakage current per linear foot of XHHW-2 wire energized at 120 VAC inside ¾” rigid steel conduit. This can be roughly calculated given the published dielectric constant and insulation resistance for the specific wire used, and estimating the average distance between the copper conductor core and the inner surface of the conduit along a given length.

Based on the 1 µA/ft. estimation, a 450 foot length of wire run through a grounded conduit should produce as around 450 µA. Given that the isolation panel contributes up to 50 µA of leakage current internally, the total cumulative leakage current would be around 500 µA. With the maximum allowable for new constructions per NFPA set at 600 µA, this leaves a moderate 100 µA margin. See the figure on the next page for further explanation.

Based on the calculations you can see it may be possible to connect up 550 feet of total wire length or even slightly more and still satisfy the minimum ground impedance specification. Understand however, that these guidelines are based on typical values, and other factors such as conduit size and fill, number of conductor terminations, and even humidity can play a role. It is therefore recommended that at least a small safety factor be included when laying out circuit paths.
System cumulative circuit length = \((a + b + \ldots + m)\) ft.
- Recommended maximum \(\leq 450\) ft.

**NOTE:** Measurement is based on length of parallel circuit pairs (L1 & L2), NOT sequence length (L1 + L2).