WHITE PAPER

By Rich Scroggins and Ravi Thapa

Emergency Generator Set Start Signal Integrity

NEC 2017 has new requirements for emergency generator start control wiring between the transfer equipment and the emergency generator. This paper discusses the new requirement and wiring installation to meet the new requirement.

A Generator engine is typically started with normally open contacts or normally closed contacts at the transfer equipment know as remote start contacts. When the loads require generator power the remote start contacts are closed to start the generator engine. The start signal contacts need to be connected between the generator and the transfer equipment. Previous code installations requirements generally did not require monitoring of the remote start signal connections. If the remote start circuit is broken, disconnected or shorted then there was no means to indicate it to the operator which results in power supply failure during normal source failure. Monitoring and alarming the integrity of start signal means the operator could take proactive approaches to fix the issue.

NEC 2017 new requirements from Article 700.10 (D)(3) generator control wiring

"Control conductors installed between the transfer equipment and the emergency generator shall be kept entirely independent of all other wiring and shall meet the conditions of 700.10(D)(1). The integrity of the generator control wiring shall be continuously monitored. Loss of integrity of the remote start circuit(s) shall initiate visual and audible annunciation of generator malfunction at the generator local and remote annunciator(s) and start the generator(s)."

The new code requires the remote start signal to be continuously monitored. Further, the code requires the generator(s) to be started on loss of integrity of the remote start signal to ensure emergency applications have a healthy backup source.

A Tentative Interim Amendment was submitted and processed by the National Electrical Code Panel 13 and the NEC Correlating Committee, and was issued by the Standards Council on August 14, 2018, with an effective date of September 3, 2018.

New code language – 2020 code and TIA

Control conductors installed between the transfer equipment and the emergency generator shall be kept entirely independent of all other wiring and shall meet the conditions of 700.10(D)(1). The integrity of the generator remote start circuit shall be monitored for broken, disconnected or shorted wires. Loss of integrity shall start the generator(s).

The amendment on the code language has removed continuous monitoring and visual/audible annunciation requirements. The new code language requires monitoring for broken, disconnected or shorted wires only and the generator(s) need to be started on loss of integrity of the start signal.

The requirement could be met with either one of the following methods:

1) Integrity contacts ('A' and 'B' contacts)

2) Monitored network start signal

This paper will discuss how integrity contacts method could meet the new NEC 700.10 (D)(3) requirements.

Note: Same requirement and TIA applies to Fire Pumps - 695.14 (F)

Aux 'A' and Aux 'B' contacts can be used for remote monitoring the status and integrity of a circuit. Aux 'A' is the normally open contact and Aux 'B' is the normally closed contact output of the monitoring signal at an equipment. Below is a table that shows the various state position of Aux 'A' and Aux 'B' and the fault results.

Table 1. Integrity contact monitor status

Input position 'A' at remote monitoring unit	Input position 'B' at remote monitoring unit	Results
Closed	Open	Normal (No fault)
Open	Closed	Normal (No fault)
Open	Open	Abnormal (Fault)
Closed	Closed	Abnormal (Fault)

Table 1 shows under normal circumstance the contacts will be in opposite states. When both Aux 'A' and 'B' contacts status is in identical state a fault condition exists.

a) Start signal integrity normal operation with single transfer equipment

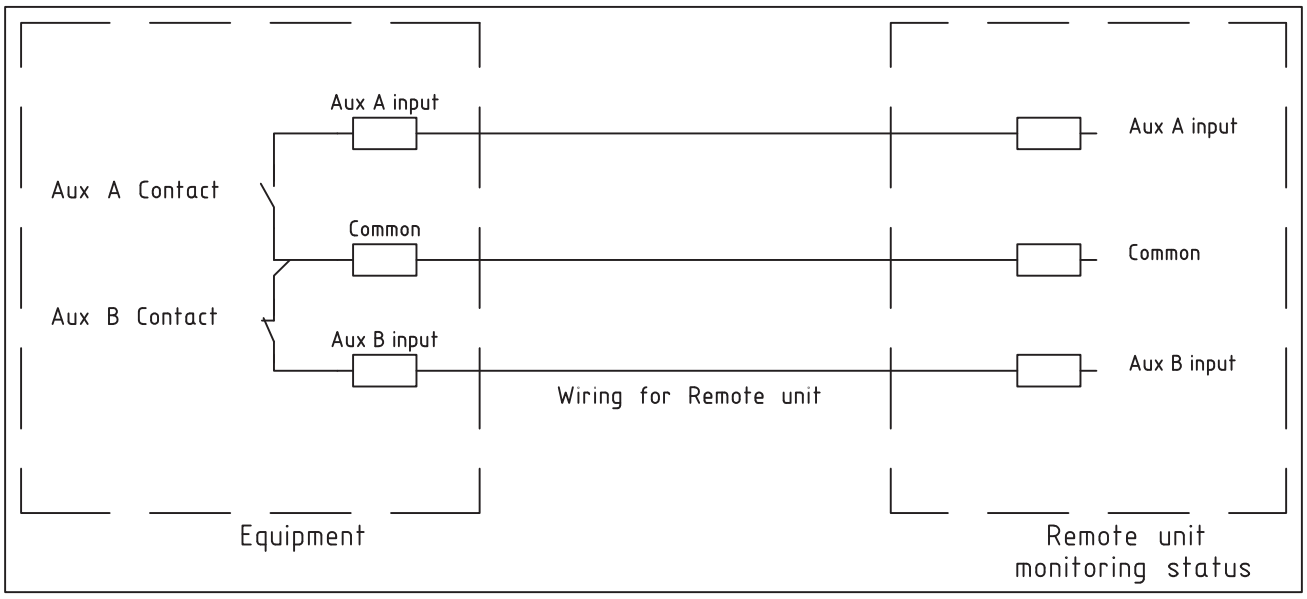


Figure 1. Remote start and start signal integrity wiring for a single transfer equipment and an emergency generator set

Figure 1 shows remote start signal connection between a transfer equipment and an emergency generator set. Aux 'A' contact is the engine start input and Aux 'B' contact is signal integrity input. Generally, when the loads are supplied by the normal source at the transfer equipment Aux 'A' the normally open contact is held closed and Aux 'B' the normally closed contact is held open with the emergency genset on standby condition. This configuration results in the normally open contact to be closed and normally closed contact to be open for normal operation with no generator set start and no start integrity fault. On normal source failure, the normally open held closed contact opens to start the emergency generator and the normally closed Aux 'B' contact held open now closes. This configuration results in the normally open contact to be open and normally closed contact to be closed with emergency generator set start and no start integrity fault. The loads are supplied by the standby emergency generator set. On the return of the normal source the transfer equipment retransfers to the normal source where the contact position returns to the original state with the loads being fed via the normal source and the emergency generator returns to standby condition.

b) Start signal integrity fault (Disconnected start signal) during normal operation with single transfer equipment

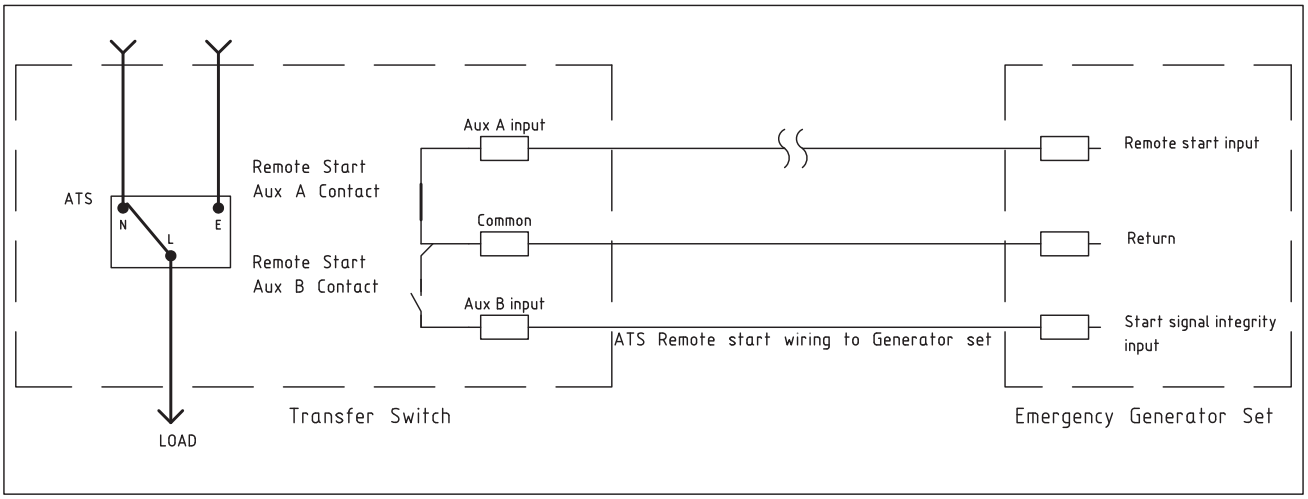


Figure 2. Disconnected remote start and signal integrity wiring for single transfer equipment and an emergency generator set

During normal operation of the system if there is a disconnect on the remote start wiring as shown in figure 2. The Aux 'A' contact is closed and the Aux 'B' contact is open. However, the remote start input at the emergency generator sees an open contact input due to the disconnect resulting emergency generator start. At the same time the start signal integrity input is still open because of the Aux 'B' contact held open at the transfer equipment. Identical contact inputs at the emergency generator set remote start and start signal integrity could be declared as integrity fault. Thus, the generator set runs on a integrity failure.

c) Start signal integrity fault (Disconnected start signal) during an outage with single transfer equipment

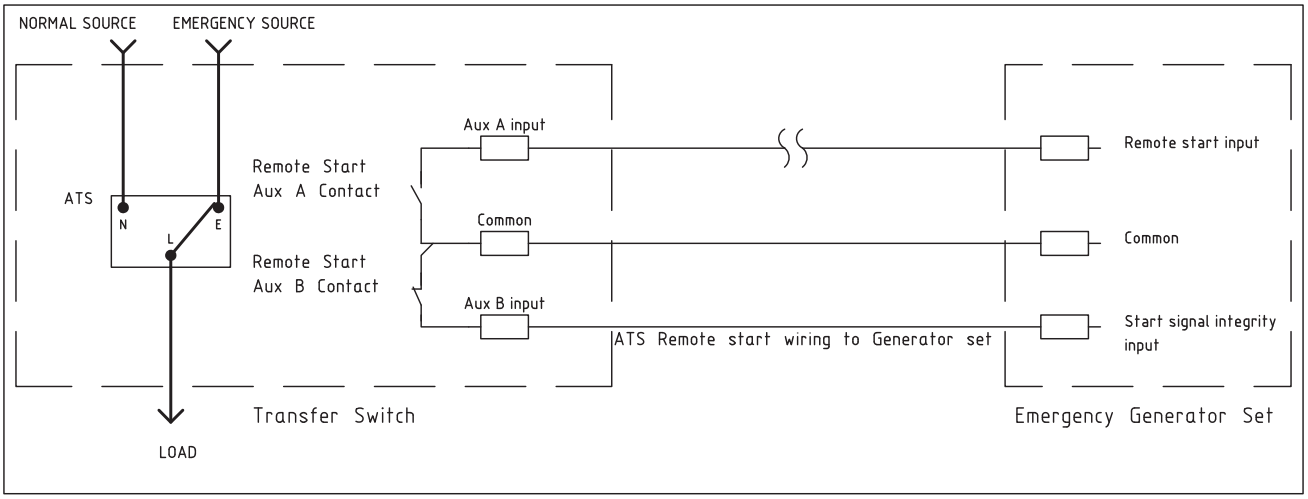


Figure 3. Disconnected remote start and signal integrity wiring for a single transfer equipment and an emergency generator set

During an outage the remote start signal contact Aux 'A' is open and the Aux 'B' contact is closed where the loads are supplied via the emergency generator set. If a disconnect on the remote start signal occurs at this condition the remote start input contact at the generator remains open. At the same time the normally closed input contact remains closed. Thus, the emergency generator runs on without integrity fault. However, if the normal source returns and the loads are fed via the normal source then the normally open contact at the transfer equipment is closed and the normally closed contact is open whereas the remote start input at the emergency generator set is open due to the disconnect. Also, the integrity input contact is open. With identical states of the remote start and integrity input contacts at the generator set, the generator set keeps running with integrity failure.

d) Start signal integrity fault (Shorted start signal) during normal operation with single transfer equipment

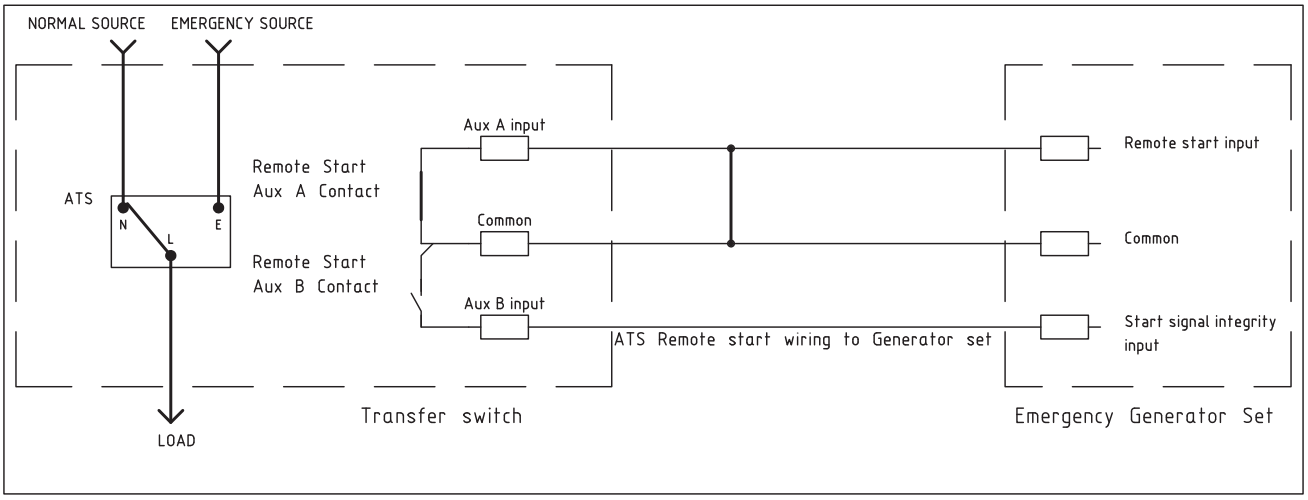


Figure 4. Shorted remote start and start signal integrity wiring for a single transfer equipment and an emergency generator set

If a short circuit on the start signal occurs during normal operation when the normal source is supplying the loads as shown in figure 4. The remote start input contact is closed at the generator set due to the short circuit whereas the input contact is open at the emergency generator integrity input. With no remote start signal, the generator set remains on standby. If an outage occurs on this condition, the normally closed contact Aux 'B' is closed at the transfer equipment. This means both the remote start and integrity input contacts at the generator set are closed. With identical input contact states, the generator starts on integrity failure.

Below is the table for different failure conditions with expected monitoring results:

Table 2. Remote start and start signal integrity wiring monitoring results for a single transfer equipment

Operation	Transfer equipment (ATS)			Emergency generator		
	Start command	N/O contact	N/C contact	Remote start input	Integrity input	Results
Normal operation	No start	Closed	Open	Closed	Open	No start, no integrity fault
Normal operation	Start	Open	Closed	Open	Closed	Start, no integrity fault
Signal wire falls off	No start	Closed	Open	Open	Open	Start, integrity fault
Signal wire falls off	Start	Open	Closed	Open	Closed	Start, no integrity fault
Signal short circuit	No start	Closed	Open	Closed	Open	No start, no integrity fault
Signal short circuit	Start	Open	Closed	Closed	Closed	Start, integrity fault
Total power loss at ATS	N/A	Closed	Open	Open	Closed	Start, no integrity fault

e) Start signal integrity normal operation with multiple transfer equipments

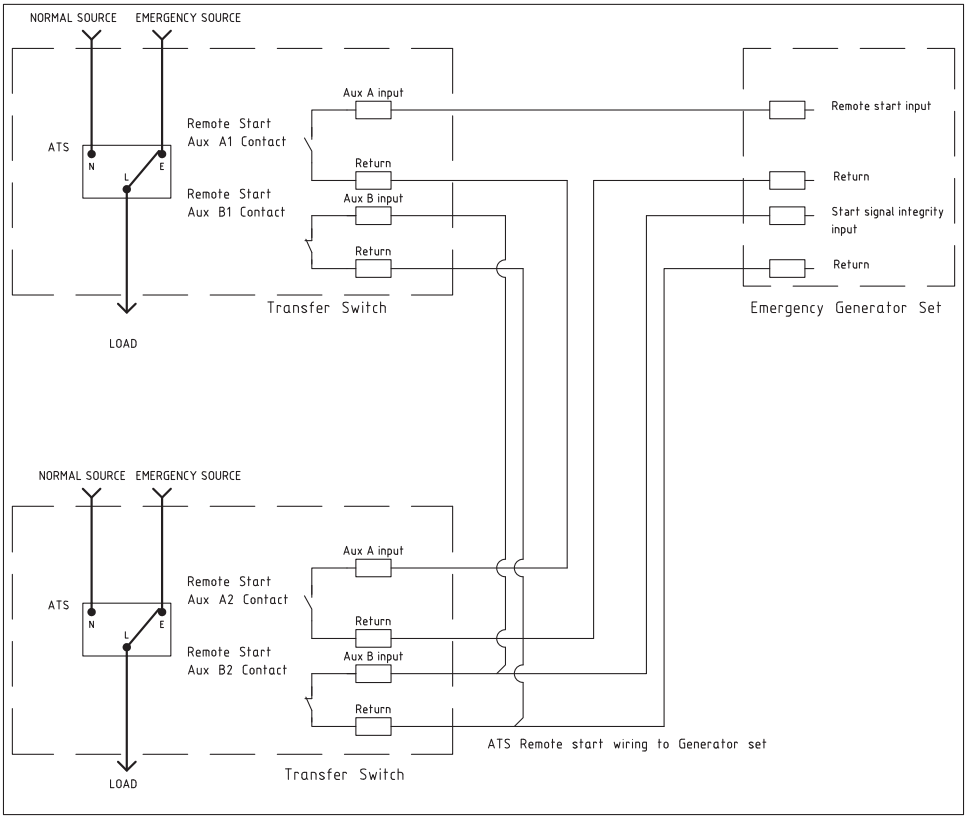


Figure 5. Remote start and start signal integrity wiring for multiple transfer equipments and an emergency generator set

When multiple transfer equipments are supplied by the same generator set, start signal integrity could be monitored with similar designs concept discussed earlier. However, the normally open N/O contacts held closed for normal condition should be wired in series and the normally closed N/C contacts held open for normal condition should be wired in parallel as shown in figure 5 to the generator set remote start and signal integrity inputs. One key difference on the start contact discussed earlier is that form C contact is not used but discrete N/O and N/C are used. If a form C type of start contact is available at the transfer equipment it needs to be converted to discrete N/O and N/C contact outputs.

For a normal operation where the normal source supplies the loads and the emergency source is on standby. The normally open remote start contacts 'A1' is held closed whereas the normally closed integrity monitoring contact 'B1' is held open. Similarly, for the second transfer the normally open remote start contacts 'A2' is held closed whereas the normally closed integrity monitoring contact 'B2' is held open. The series connected normally open Aux 'A' contacts are closed and the normally closed Aux 'B' contacts wired parallel are open for normal operation with no generator set start and no start integrity fault.

During normal source failure on any transfer equipment, the normally open 'A' contacts held closed open to start the emergency generator set source while the normally closed contacts 'B' held open now closes with no integrity failure.

f) Start signal integrity fault (Disconnected start signal) during normal operation with multiple transfer equipments

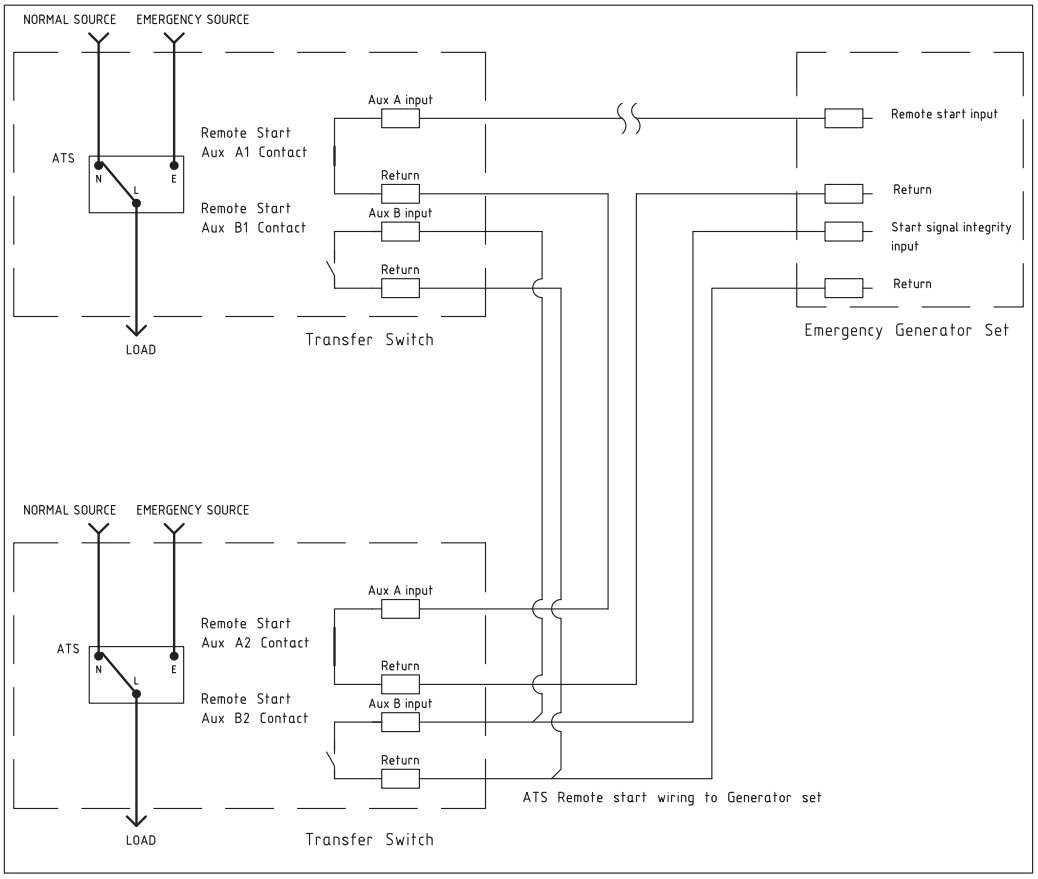


Figure 6. Disconnected remote start and start signal integrity wiring for multiple transfer equipments and an emergency generator set

For a disconnect on the start signal during a normal operation as shown in figure 6, the remote start signal contact outputs at the transfer equipments Aux 'A' are closed. The contacts Aux 'B' are open. However, the generator set remote start input sees an open input due to the disconnect. At the same time the Aux 'B' contacts are open. The identical state condition of open input contacts at the generator remote start and remote start integrity inputs could be declared as start signal integrity fault and the generator set would be started on integrity failure.

g) Start signal integrity fault (Disconnected start signal) during an outage operation with multiple transfer equipments

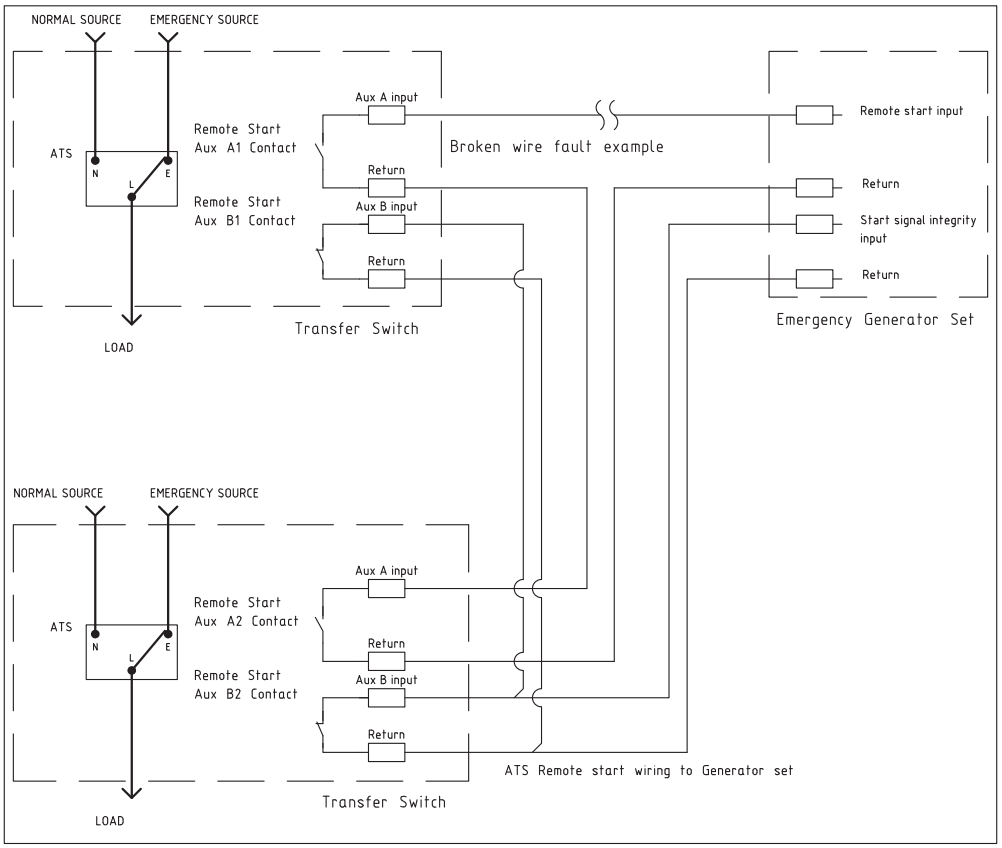


Figure 7. Remote start and start signal integrity wiring for multiple transfer equipments and an emergency generator set

For a system as shown in figure 7, during an outage the remote start signal contact outputs at the transfer equipments Aux 'A' are open and Aux 'B' are closed where the loads are supplied via the generator set source. For a disconnected start signal the generator set remote start input remains open due to the disconnect of the wiring. At the same time the Aux 'B' contacts are closed on transfer equipment. The generator set keeps running like an outage. When the normal source returns the normally open contacts are held closed however the remote start input at the generator set sees an open contact input. Similarly, the normally closed contacts are open at the transfer equipments. This condition of open contacts at the generator remote start and remote start integrity inputs could be declared as start signal integrity fault and the generator set would be running on integrity failure.

h) Start signal integrity fault (Shorted start signal) with multiple transfer equipments

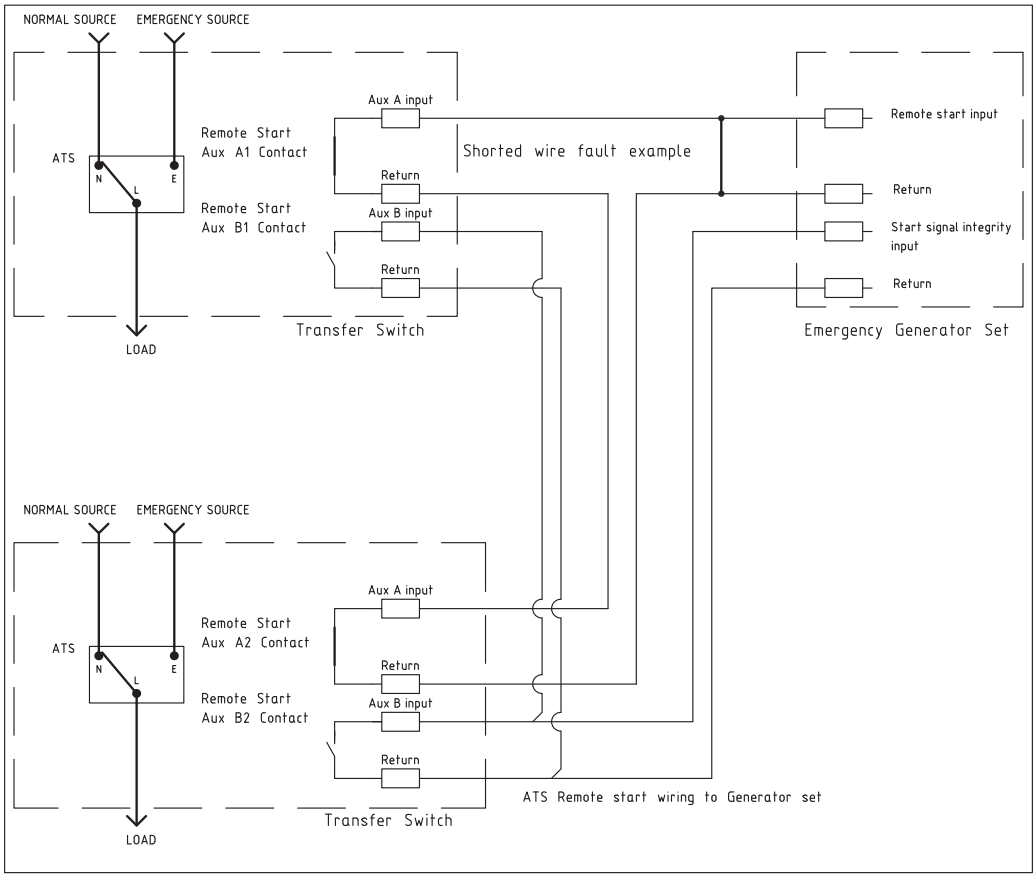


Figure 8. Remote start and start signal integrity wiring for multiple transfer equipments and an emergency generator set

For a normal condition when the normal source is supplying the load, the contact outputs 'A' at the transfer equipments are closed. Similarly, the contacts 'B' are open where the loads are supplied via normal source and generator set is on standby. For a faulty remote start wiring condition as short circuit as shown in figure 8 the remote start input at the generator set will not see any change in state. No integrity fault will be resulted in this condition. If there is a normal source failure with the remote start wire shorted then the output contact 'A' at the transfer equipment is open. However, the generator set remote start input sees closed input due to the shorted wiring. At the same time the Aux 'B' contacts closed on transfer equipment with normal source failure resulting closed contact input at the generator integrity input. This condition of closed input contacts at the generator remote start and remote start integrity inputs could be declared as start signal integrity fault and the generator set would be started on integrity failure.

Below is the table for different failure conditions with expected monitoring results:

Table 3. Faulty Remote start and start signal integrity wiring for a multiple transfer equipment

Operation	Transfer equipment 1 (ATS 1)			Operation	Transfer equipment 2 (ATS 2)			Emergency generator		
	Start command	N/O contact	N/C contact		Start command	N/O contact	N/C contact	Remote start input	Integrity input	Result
Normal	No Start	Closed	Open	Normal	No Start	Closed	Open	Closed	Open	No start, no integrity fault
Normal	No Start	Closed	Open	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Normal	Start	Open	Closed	Normal	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Normal	Start	Open	Closed	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Wire falls off	No Start	Closed	Open	Normal	No Start	Closed	Open	Open	Open	Start, integrity fault
Wire falls off	No Start	Closed	Open	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Wire falls off	Start	Open	Closed	Normal	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Wire falls off	Start	Open	Closed	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Wire falls off	No Start	Closed	Open	Wire falls off	No Start	Closed	Open	Open	Open	Start, integrity fault
Wire falls off	No Start	Closed	Open	Wire falls off	Start	Open	Closed	Open	Closed	Start, no integrity fault
Wire falls off	Start	Open	Closed	Wire falls off	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Wire falls off	Start	Open	Closed	Wire falls off	Start	Open	Closed	Open	Closed	Start, no integrity fault
Short Circuit	No Start	Closed	Open	Normal	No Start	Closed	Open	Closed	Open	No Start, no integrity fault
Short Circuit	No Start	Closed	Open	Normal	Start	Open	Closed	Closed	Closed	Start, integrity fault
Short Circuit	Start	Open	Closed	Normal	No Start	Closed	Open	Closed	Closed	Start, integrity fault
Short Circuit	Start	Open	Closed	Normal	Start	Open	Closed	Closed	Closed	Start, integrity fault
Loss of B+	No Start	Open	Closed	Normal	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Loss of B+	No Start	Open	Closed	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Loss of B+	Start	Open	Closed	Normal	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Loss of B+	Start	Open	Closed	Normal	Start	Open	Closed	Open	Closed	Start, no integrity fault
Loss of B+	No Start	Open	Closed	Wire falls off	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Loss of B+	No Start	Open	Closed	Wire falls off	Start	Open	Closed	Open	Closed	Start, no integrity fault
Loss of B+	Start	Open	Closed	Wire falls off	No Start	Closed	Open	Open	Closed	Start, no integrity fault
Loss of B+	Start	Open	Closed	Wire falls off	Start	Open	Closed	Open	Closed	Start, no integrity fault

If multiple generator sets are present in the system, the remote start output and integrity output at the transfer switch could be wired as discussed in various wiring diagrams in this paper and then the remote start input and integrity input at the emergency generators could be wired from one generator set to another generator set as shown in figure 9.

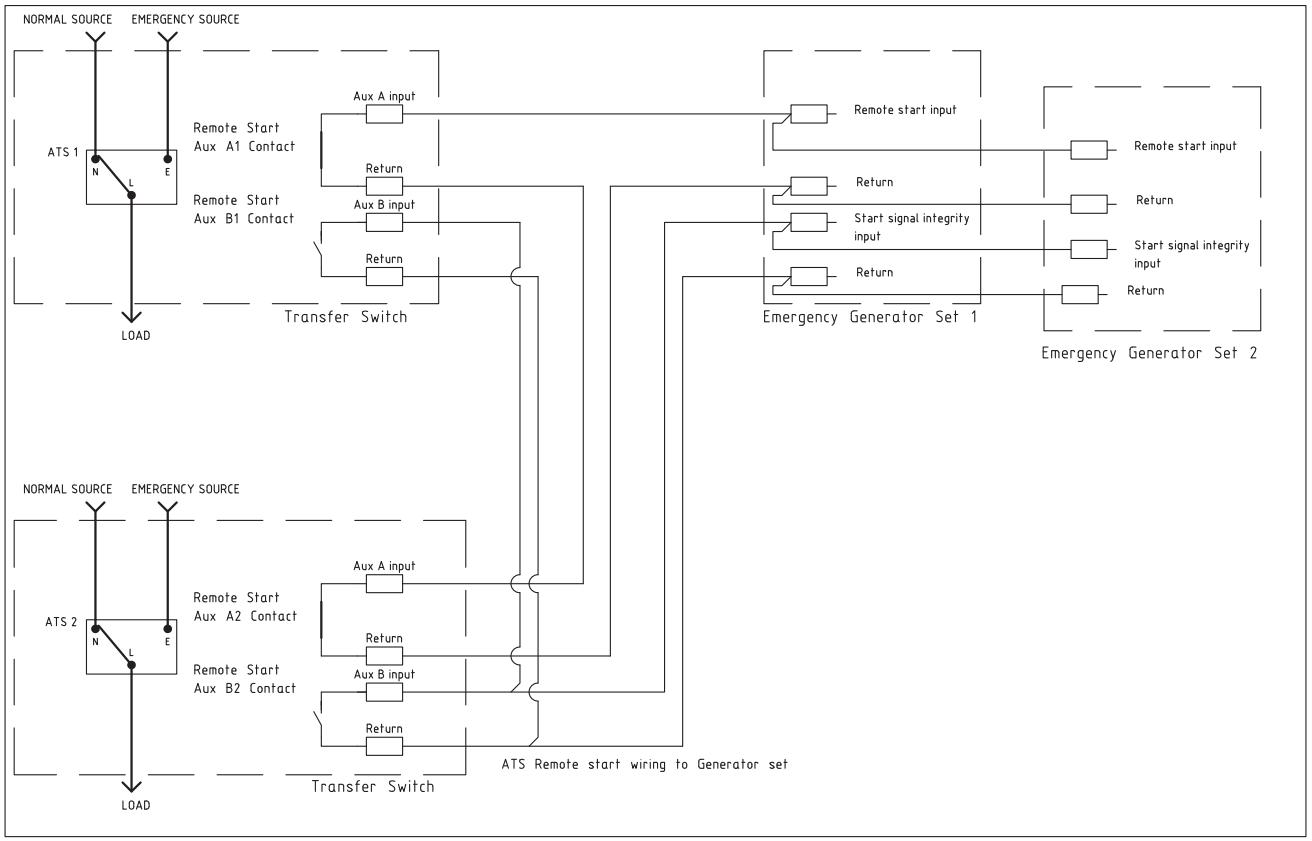


Figure 9. Remote start and start signal integrity wiring for multiple transfer equipments and multiple emergency generator sets

Summary

Integrity contacts circuits discussed in this paper could be used to satisfy the new NEC 700.10 requirements to monitor generator remote start signal for broken, disconnected or shorted wires.

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