Wide-Area Control System Advanced Auto-Restoration

1 Descriptions of Function

All prior work (intellectual property of the company or individual) or proprietary (non-publicly available) work should be so noted.

1.1 Function Name

Advanced Auto-Restoration

1.2 Function ID

IECSA identification number of the function

T-4.1,T-4.2,T-4.3,T-4.15,T-6,T-6.10,T-6.17,T-6.19,D-4,D-5,D-6,D-7,L-2.2.1,L-2.2.2,L-3.2,L-3.4,L-3.8,C-9.4

1.3 Brief Description

Describe briefly the scope, objectives, and rationale of the Function.

The purpose of advanced auto-restoration is to automatically restore power to un-faulted sections of a line or feeder, after a fault is isolated, in networks having complex topologies and multiple organizational boundaries.

1.4 Narrative

A complete narrative of the Function from a Domain Expert's point of view, describing what occurs when, why, how, and under what conditions. This will be a separate document, but will act as the basis for identifying the Steps in Section 2.

Currently, automatic restoration of service is performed only within a restricted set of conditions and network topologies, as described in the WAMACS Automated Controls Baseline use case. In the near future, it is expected that these restrictions will be removed and the automation system will be able to restore power in systems which:

- There are multiple sources from which to restore power

- The multiple sources may belong to different organizations
- There are multiple possible connection points between the sources
- It is necessary to split the de-energized load into sections because any one source cannot re-energize the whole load

The remainder of this narrative describes an example scenario illustrating these capabilities.

1.4.1 Initial State

As shown in Figure 1, two neighboring substations are connected in a manner to make traditional auto-restoration possible, in other words:

- Per typical utility operation, there is breaker located in the substation connected to each feeder, provided with an automatic reclosing function. These are labeled 1A1, 1B1, 2A1, and 2B1 in the figure, following the naming convention <substation1/2><feederA/B><switch/breaker#>.
- Normally-closed switches are located at intervals along each feeder to permit auto-sectionalizing around a fault. (e.g. 1B2, 1B3, 1B4). These switches are typically of the “no-load break” variety, for economic reasons. They can open only when there is no load on the line. Some may be of the “load break” variety, which can open under normal current. Usually only those devices at the head of the feeder (such as 1A1, 1B1 etc.) will be “fault interrupting” breakers capable of opening under fault current.
- A normally-open switch is located at the end of adjacent feeders. (e.g. 1C or 2C). This switch can be closed to share load or restore power from one feeder to the other.
- Each breaker and switch is monitored and controlled by an Intelligent Electronic Device (IED).
- A Substation Computer (SC) in each substation gathers information and controls the IEDs connected to its feeders. It reports to the Operator for that utility by way of a Graphical User Interface (GUI).

In this example, the two adjacent sets of feeders can also be connected to each other (if necessary) using a number of normally-open switches (1X, 1Y and 1Z). This interconnection is rarely performed because the two substations belong to different utilities. In this example, the interconnection switches are owned by the utility that controls Substation 1. However, Operator 1 must have approval from Operator 2 before closing any of these switches.

The scenario begins with each IED reporting its downstream load and switch status to the Substation Computer. For the purposes of this example, we assume that *all* this information is reported to *both* Substation Computers. There are two ways to do this:

- Each IED reports its data separately to each Substation Computer
- Each IED only reports to its "own" Substation Computer, and the Substation Computers exchange information.

The latter case is most likely to be implemented because:

- It reduces the number of communications connections between the two utilities, which is desirable for security reasons.
- It reduces the bandwidth and processing power required by each IED.

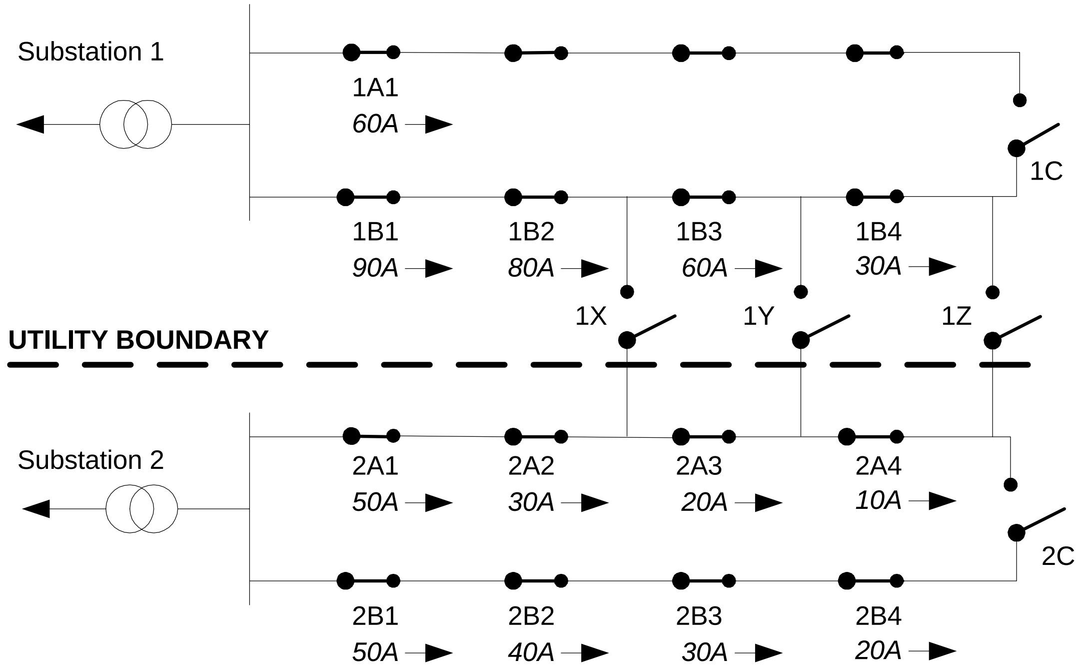


Figure 1 Initial System State

From the current data reported by each IED (shown in italics with arrows), the Substation Computers can calculate the load on each individual section of the feeders. This example assumes that the maximum capacity limit on each feeder is 100A. Feeder 1B, in that case, is operating near capacity, while the other feeders are about 50% loaded.

1.4.2 Fault Detection

As shown in Figure 2, a fault occurs on feeder 1B between switches 1B2 and 1B3. Breaker 1B1 trips and de-energizes 90A of load, including 60A that is downstream from the fault.

All IEDs on feeder 1B report to Substation Computer 1 the fault and the loss of current. Those IEDs that saw the fault current (1B1 and 1B2) may send an estimated distance to the fault. IED 1B1 reports that it has tripped and has started reclosure timers. Substation Computer 1 forwards the information to Substation Computer 2, but SC2 takes no action because the fault is not in its territory.

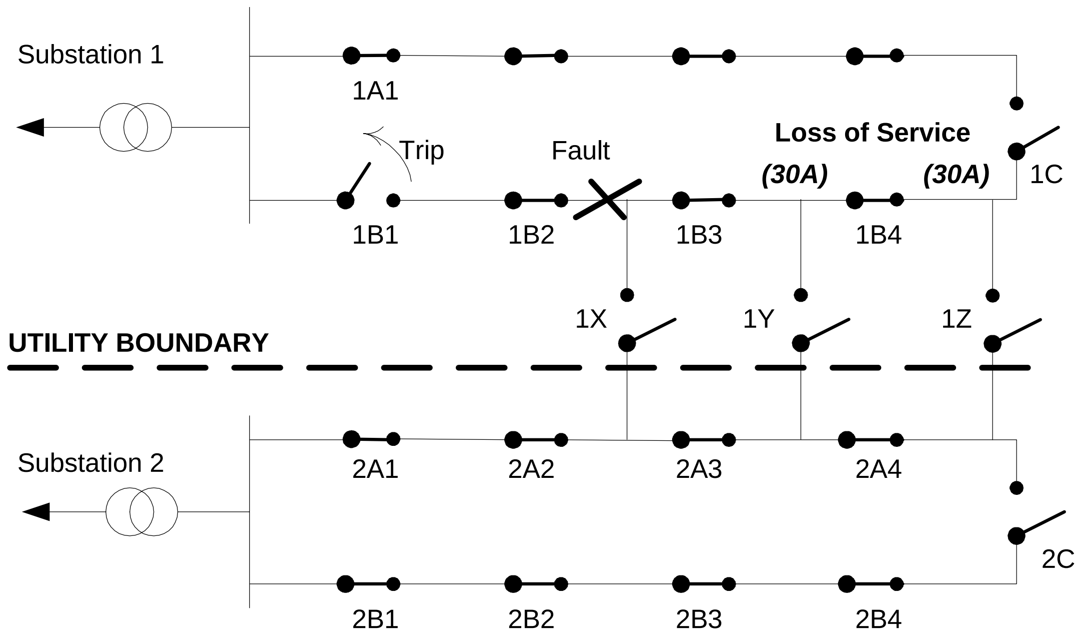


Figure 2 Fault Detection

1.4.3 Auto-Sectionalization

As shown in Figure 4, the IEDs on feeder 1B take action to isolate, or auto-sectionalize, the fault. There are two possible methods for doing so, with different communications requirements.

- **High-Speed Communication.** One possible method is that Substation Computer 1 determines which two switches (1B2 and 1B3) to open using fault direction and distance information provided by the IEDs. This method would require fast communication between the 1B IEDs and SC1, in order to open the switches between reclosings of the breaker (measured in seconds). It would likely also require the IEDs to provide a specialized communications service, i.e. “open the next time you see zero current”.

- **Fault-Interruption Counting.** A more robust and distributed method would be for each IED to be programmed to open its switch after a pre-configured reclosure attempt. Each IED would open its switch under the following conditions:

    - The IED has observed fault current
    - The IED has seen the fault current drop to zero, indicating the breaker has tripped
    - These two conditions have occurred a pre-configured number of times. The number is different for each IED on the feeder.

Figure 3 illustrates how this occurs in the example. No IED is permitted to open its switch between the initial fault and the first reclosure attempt, in case the fault is transient. 1B4 is permitted to open its switch between the first and second reclosure attempts, but does not do so. Because 1B4 is downstream from the fault and has no other source of current, it does not observe the fault current and its opening conditions are therefore not met. Similarly, 1B3 does not observe fault current and so does not open in its time window.

IED 1B2, however, has seen the same current as 1B1, and has been counting the fault interruptions. After the third reclosure attempt, 1B2 opens its switch, isolating the fault from any source of current. This is **auto-sectionalization**, and is shown as step (1) in Figure 4. When 1B1 recloses the fourth time, it is successful, and 10A of load is restored to that section of feeder 1B. This is step (2) in Figure 4.

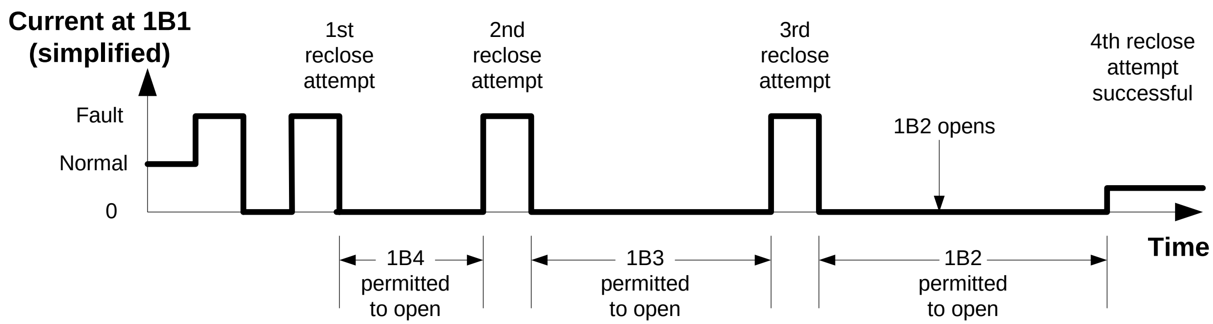


Figure 3 Fault-Interruption Counting for Auto-Sectionalization

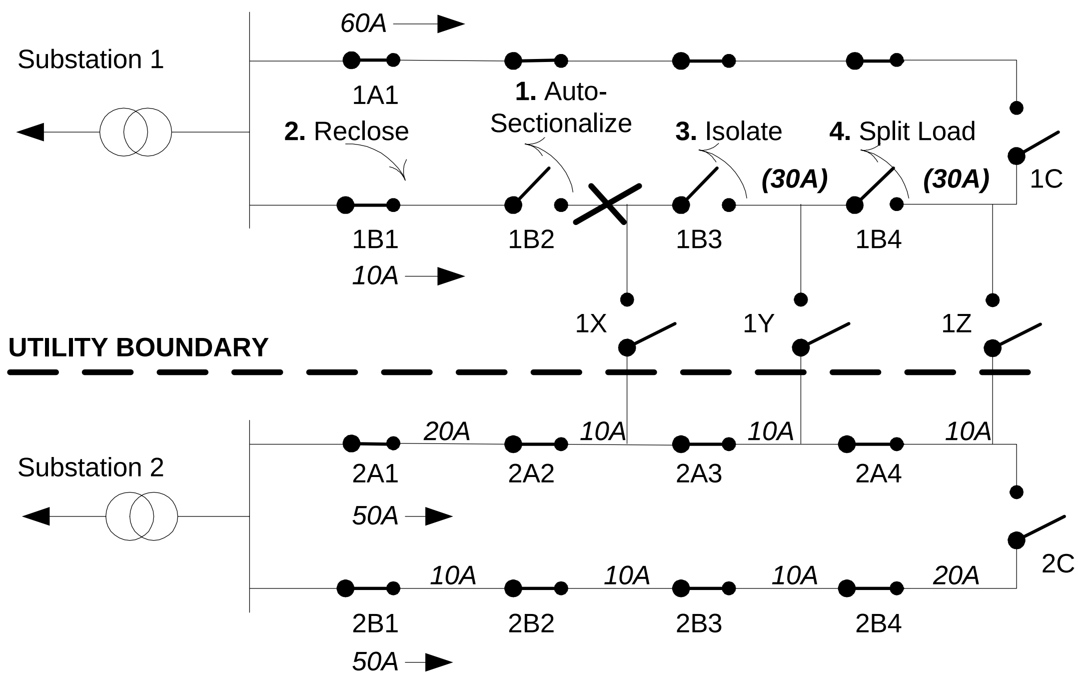


Figure 4 Auto-Sectionalization and Load Splitting

1.4.4 Isolating the Fault

The final step in auto-sectionalization, shown in step (3) of Figure 4, is to isolate the fault. Substation Computer 1 observes that 1B3 and 1B4 have reported zero current and voltage without having reported fault current. It therefore determines (possibly with the assistance of distance-to-fault data from 1B1 and 1B2) that the fault is between 1B2 and 1B3. Substation Computer 1 recommends to Operator 1 that switch 1B3 be opened in order to isolate the fault. Operator 1 confirms this operation, and SC1 sends the message to 1B3 causing it to open.

1.4.5 Load Splitting

Whichever auto-sectionalizing method is used, the fault is now isolated and auto-restoration can begin. Substation Computer 1 reviews the data provided prior to the fault. It calculates the loading on each segment of each feeder, as shown in Figure 4. It determines that there is 60A of load that can be restored.

However, the "traditional" solution, to close switch 1C, will not solve the whole problem. Feeder 1A is already loaded at 60A. If it accepts the whole downstream load of 60A, it will be overloaded, since the example began with the assumption of 100A maximum limit per feeder.

The Substation Computer determines that it will be necessary to "split" the downstream load and re-energize it from multiple sources. Substation Computer 1 recommends to Operator 1 that switch 1B4 be opened, receives confirmation from Operator 1, and opens the switch by sending a message to 1B4. This is step (4) in Figure 4.

1.4.6 Auto-Restoration

The final steps in auto-restoration are shown in Figure 5. Utility 1 has a policy in place that load is to be restored from Utility 1 sources whenever possible. Therefore Substation Computer 1 recommends that switch 1C be closed, rather than, for instance, switch 1Z. Operator 1 confirms this operation and SC1 sends the message to IED 1C, restoring 30A of service.

Substation Computer 1 recommends that switch 1Y be closed to restore the remaining un-faulted section of feeder between 1B3 and 1B4. Operator 1 contacts Operator 2 at Utility 2, requesting permission to close switch 1Y.

Before making this decision, Operator 2 does the following:

- Reviews the sequence of events logs generated by SC2 showing the auto-sectionalizing sequence.
- Confirms that Utility 1 has isolated the fault between 1B2 and 1B3.
- Confirms from records generated by SC2 that the de-energized section between 1B3 and 1B4 previously was loaded at 30A.
- Checks on the SC2 GUI that feeder 2A can handle the additional 30A load.

Finally, Operator 2 contacts Operator 1, giving permission to close switch 1Y. Operator 1 confirms the operation with SC1, which sends the message to 1Y and restores the remaining 30A of service.

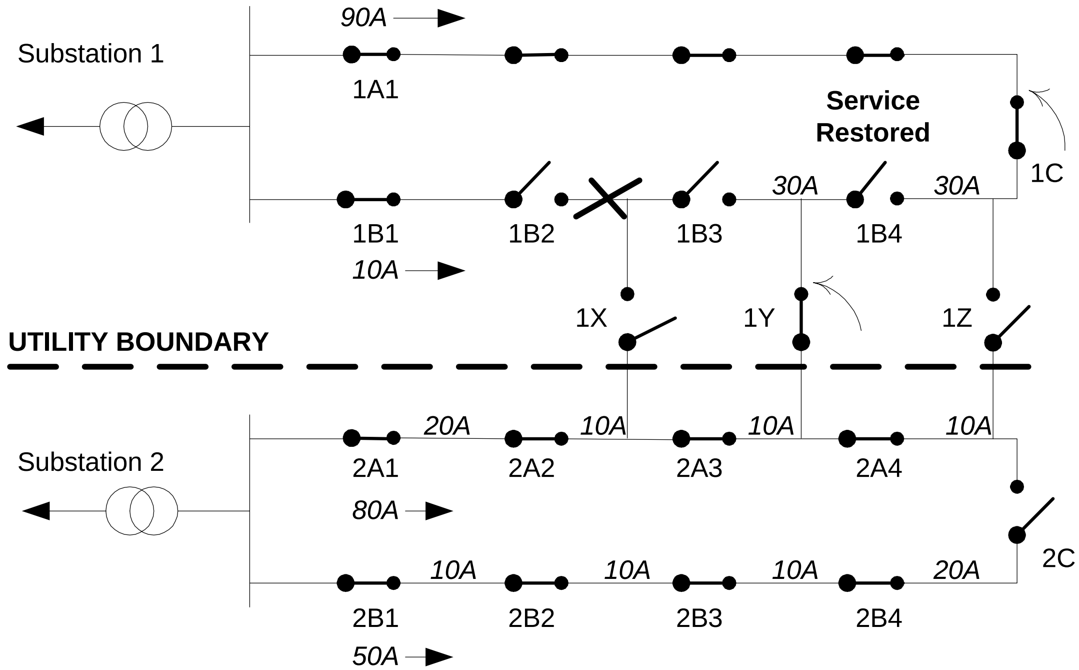


Figure 5 Auto-Restoration

1.4.7 Load Balancing

Following auto-restoration, feeder 1A is loaded at 90A and 2A is loaded at 80A, while 2B is only loaded at 50A. Operator 2 may choose to close switch 2C in order to lighten the load on feeder 2A.

In theory, the whole system could be more efficiently loaded by also closing switch 1Z. However, neither Substation Computer would make this recommendation because:

- The power on the two feeders is likely incompatible due to differences in frequency, voltage, and phase angle. Therefore, it would be necessary to open 1C before closing 1Z.

- Opening 1C would cause a momentary outage downstream of 1B4. Furthermore, if 1C was not a "load break" switch, it would be necessary to first break the load at 1A1, meaning that the outage would occur for all of feeder 1A.
- Utility 1 would lose the 30A of load downstream of 1B4 to Utility 2 until the fault could be repaired. This would be unacceptable from a business point of view.

1.4.8 Summary

Performing advanced auto-restoration will require the following measures beyond those required for existing auto-restoration mechanisms:

- Real-time sharing of data between Substation Computers
- Calculation of loads on each feeder or line section, and storing these recent historical values in the Substation Computer.
- More advanced logic in each Substation Computer to evaluate each possible switching action, perhaps on the order of the Contingency Analysis programs currently used by EMS stations.
- Reliable communications between neighboring operators, either by voice or by data
- One of the following features:
    - **Full breakers and protection relays on each section**, or "load break" or "fault-interrupting" switches. Utilities are unlikely to do this because of the significantly higher cost.
    - **Fault-Interruption counting**, as discussed in this example. Fault-interruption counting has one major drawback: Ideally, it requires the same number of reclosures as there are switches on the feeder. Typically, utilities do not use a high number of reclosures because:

- It causes excessive wear on the breaker

- It annoys the customers, who see multiple small outages within a short period of time.

Therefore it is rare to see more than two or three reclosures. This example, with four reclosures, would be extremely rare. This limits the granularity with which load can be restored, and increases the number of subscribers affected by an fault.

- **High-speed communications** between remote IEDs and the substation computer. In this example, it would permit the Substation Computer to immediately determine that 1B2 and 1B3 switches should open, and do so quickly, between the first and second reclosings of breaker1B1. This is shown as an alternate scenario in the use case below.

1.5 Actor (Stakeholder) Roles

Describe all the people (their job), systems, databases, organizations, and devices involved in or affected by the Function (e.g. operators, system administrators, technicians, end users, service personnel, executives, SCADA system, real-time database, RTO, RTU, IED, power system). Typically, these actors are logically grouped by organization or functional boundaries or just for collaboration purpose of this use case. We need to identify these groupings and their relevant roles and understand the constituency. The same actor could play different roles in different Functions, but only one role in one Function. If the same actor (e.g. the same person) does play multiple roles in one Function, list these different actor-roles as separate rows.

Grouping (Community) '		***Group Description***
Advanced Auto-Restoration		***The actors involved in restoring service in an example scenario involving multiple power sources, multiple organizations, and load splitting.***
Actor Name	***Actor Type (person, device, system etc.)***	***Actor Description***
Utility 1, Utility 2	Organizations	Neighboring utilities with interconnections and agreements on auto-restoration. Apply policies that affect the auto-restoration algorithms on the SubstationComputerDevices
SystemOperator 1,	Persons	Control the SubstationComputerDevices. Confirm or reject auto-restoration

Grouping (Community) '		***Group Description***
Advanced Auto-Restoration		***The actors involved in restoring service in an example scenario involving multiple power sources, multiple organizations, and load splitting.***
Actor Name	***Actor Type (person, device, system etc.)***	***Actor Description***
SystemOperator 2		recommendations made by the SubstationComputerDevices
SubstationComputerDevice 1, SubstationComputerDevice 2	Devices	Apply algorithms to implement auto-restoration based on data gathered from the IEDs.
IED	Devices	IED <substation 1 or 2> <feeder A or B> <device ID number> Gather data from feeders and operate switches based on controls from the SubstationComputerDevices. The first IED on each feeder controls a "fault-interrupting" breaker with auto-reclosing function. The other IEDs control "no-load break" switches.
External	Event	Causes a fault.
System	Devices	The combined power network.

Replicate this table for each logic group.

1.6 Information exchanged

Describe any information exchanged in this template.

Information Object Name	*Information Object Description*
Switch State	Digital Input with value Open or Closed. The change of state of a switch. Includes: a point number, the quality of the point (online/offline or valid/invalid), the new state, the time the state changed, typically accurate to millisecond resolution.
Current	Analog value in Amperes. Often a twelve-bit or sixteen-bit integer that must be scaled for display in engineering units. Includes: a point number, the quality of the point, and the value. May or may not include a millisecond timestamp.
Voltage	Analog value in Volts. Often a twelve-bit or sixteen-bit integer that must be scaled for display in engineering units. Includes: a point number, the quality of the point, and the value. May or may not include a millisecond timestamp.
Trip	Digital Input with value Trip. A particular type of Switch State change that indicates through its point number that a breaker has tripped and is now open. Includes all the same data as for a Switch State change.
Fault Detected	Digital Input with value True or False. Indicates an IED has observed fault current. Includes: a point number, the quality of the point, the new state, millisecond timestamp. May also include an analog value indicating a calculated Distance to Fault.
No Current Detected	Digital Input with value True or False. Indicates an IED cannot detect any current. Includes: a point number, the quality of the point, the new state, millisecond timestamp. May not be sent as a separate indication because SubstationComputerDevice can determine it from the Current transmitted.
No Voltage Detected	Digital Input with value True or False. Includes: a point number, the quality of the point, the new state, millisecond timestamp. May not be sent as a separate indication because SubstationComputerDevice can determine it from the Voltage transmitted.
Switch Control	Digital Output with value Open or Close. Sent by the SubstationComputerDevice to change the state of a switch. Includes a point number and the requested switch state.
Request	Message to an SystemOperator, requesting that a particular action be taken, e.g. opening a particular switch. Includes: the operation to be taken (e.g. trip, close), and the location (e.g. the device name or

Information Object Name	*Information Object Description*
	feeder location). May be graphical, text, or voice.
Confirm	Confirmation from an SystemOperator to a SubstationComputerDevice that the requested operation can proceed.

1.7 Activities/Services

Describe or list the activities and services involved in this Function (in the context of this Function). An activity or service can be provided by a computer system, a set of applications, or manual procedures. These activities/services should be described at an appropriate level, with the understanding that sub-activities and services should be described if they are important for operational issues, automation needs, and implementation reasons. Other sub-activities/services could be left for later analysis.

Activity/Service Name	*Activities/Services Provided*
Fault Detection	Identify that a fault has occurred and where it is located.
Auto-Sectionalization	Open switch(es) upstream of a fault to permit restoration of service
Fault Isolation	Open switch(es) downstream of a fault to prevent a repeated fault when service is restored. May be considered a sub-function of auto-sectionalization.
Load Splitting	Open switch(es) within a de-energized area, permitting some of the load in that area to be re-energized from different sources.
Auto-Restoration	Close switch(es) to re-apply power to a de-energized area.
Load Balancing	Open or close switch(es) to divide load between different sources and reduce load on any one source.

1.8 Contracts/Regulations

Identify any overall (human-initiated) contracts, regulations, policies, financial considerations, engineering constraints, pollution constraints, and other environmental quality issues that affect the design and requirements of the Function.

Contract/Regulation	*Impact of Contract/Regulation on Function*
Cost of “fault-interrupting” switches and breakers	Prevents installing these devices at more than one location on the feeder. Requires auto-restoration algorithms to be based around opening switches only when there is no load on the line.
Competition between neighboring utilities	Requires auto-restoration algorithms to be biased against restoring load using power from neighboring utilities.

Policy	*From Actor*	*May*	*Shall Not*	*Shall*	*Description (verb)*	*To Actor*
Use Local Power First	Utility			X	Restore power using sources from the local utility first before considering sources from other utilities.	SubstationComputerDevice
Maximum Current Limits	Utility		X		Exceed maximum current limit on any feeder	SubstationComputerDevice
“No-Load Break” Switches	Utility		X		Open switches that are under load	SubstationComputerDevice
Incompatible Feeders	Utility		X		Connect feeders that are powered by different sources and therefore have different voltage, frequency and phase angle characteristics.	SubstationComputerDevice
Permission to Link Utilities	Utility		X		Close switches linking utilities until permission is obtained from the other SystemOperator	SystemOperator
Minimum Outage	Utility			X	Minimize the length of any outage	SystemOperator and SubstationComputerDevice
Minimum Reclosing	Utility			X	Minimize the frequency and number of reclosures	SystemOperator and SubstationComputerDevice

Constraint	Type	Description	Applies to

2 Step by Step Analysis of Function

Describe steps that implement the function. If there is more than one set of steps that are relevant, make a copy of the following section grouping (Preconditions and Assumptions, Steps normal sequence, and Steps alternate or exceptional sequence, Post conditions)

2.1 Steps to implement function

Advanced Auto-Restoration

See section 2.3 for a diagram of the steps that are described in this section. This scenario illustrates the “high-speed communications” option described in the Narrative.

2.1.1 Preconditions and Assumptions

Describe conditions that must exist prior to the initiation of the Function, such as prior state of the actors and activities

Identify any assumptions, such as what systems already exist, what contractual relations exist, and what configurations of systems are probably in place

Identify any initial states of information exchanged in the steps in the next section. For example, if a purchase order is exchanged in an activity, its precondition to the activity might be ‘filled in but unapproved’.

Actor/System/Information/Contract	***Preconditions or Assumptions***
IEDs	Regularly sending existing Current, Voltage, and Switch States to SubstationComputerDevice 1.
SubstationComputerDevice 1	Regularly sending exising Current, Voltage, and Switch States to SubstationComputerDevice 2.
System	No faults existing.

2.1.2 Steps – Normal Sequence

Describe the normal sequence of events, focusing on steps that identify new types of information or new information exchanges or new interface issues to address. Should the sequence require detailed steps that are also used by other functions, consider creating a new “sub” function, then referring to that “subroutine” in this function. Remember that the focus should be less on the algorithms of the applications and more on the interactions and information flows between “entities”, e.g. people, systems, applications, data bases, etc. There should be a direct link between the narrative and these steps.

The numbering of the sequence steps conveys the order and concurrency and iteration of the steps occur. Using a Dewey Decimal scheme, each level of nested procedure call is separated by a dot ‘.’. Within a level, the sequence number comprises an optional letter and an integer number. The letter specifies a concurrent sequence within the next higher level; all letter sequences are concurrent with other letter sequences. The number specifies the sequencing of messages in a given letter sequence. The absence of a letter is treated as a default 'main sequence' in parallel with the lettered sequences.

Sequence 1:

```
1.1 - Do step 1
1.2A.1 - In parallel to activity 2 B do step 1
1.2A.2 - In parallel to activity 2 B do step 2
1.2B.1 - In parallel to activity 2 A do step 1
1.2B.2 - In parallel to activity 2 A do step 2
1.3 - Do step 3
1.3.1 - nested step 3.1
1.3.2 - nested step 3.2
```

Sequence 2:

```
2.1 - Do step 1
2.2 – Do step 2
```

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
#	*Triggering event? Identify the name of the event.*[1]	*What other actors are primarily responsible for the Process/Activity? Actors are defined in section1.5.*	*Label that would appear in a process diagram. Use action verbs when naming activity.*	*Describe the actions that take place in active and present tense. The step should be a descriptive noun/verb phrase that portrays an outline summary of the step. "If …Then…Else" scenarios can be captured as multiple Actions or as separate steps.*	*What other actors are primarily responsible for Producing the information? Actors are defined in section1.5.*	*What other actors are primarily responsible for Receiving the information? Actors are defined in section1.5.* *(Note – May leave blank if same as Primary Actor)*	*Name of the information object. Information objects are defined in section 1.6*	*Elaborate architectural issues using attached spreadsheet. Use this column to elaborate details that aren't captured in the spreadsheet.*	*Reference the applicable IECSA Environment containing this data exchange. Only one environment per step.*
1A	Fault	External	Report Fault	IEDs upstream from the fault report seeing fault current	IED 1B1, IED 1B2	SubstationComputerDevice 1	Fault Detected		Deterministic Rapid Response Intra-Sub
1B	Loss of current and voltage	External	Report Loss of Service	IEDs downstream from the fault report loss of current and voltage	IED 1B3, IED 1B4	SubstationComputerDevice 1	No Current Detected, No Voltage Detected		Deterministic Rapid Response Intra-Sub
2.1		IED 1B1	Initial Trip	First feeder IED (relay) trips breaker and reports the action. Starts reclosure timer.	IED 1B1	SubstationComputerDevice 1	Trip		Deterministic Rapid Response Intra-Sub
2.2	Recloser timer expires	IED 1B1	First Reclose Attempt	Upon expiry of reclosure timer, first IED recloses the breaker. Reports the action.	IED 1B1	SubstationComputerDevice 1	Switch State (close)		Deterministic Rapid Response Intra-Sub

[1] Note – A triggering event is not necessary if the completion of the prior step – leads to the transition of the following step.

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
2.3	Fault	External	Report Fault	IEDs upstream from the fault report seeing fault current again. This message indicates that the fault was not intermittent and that the SC should attempt to auto-sectionalize.	IED 1B1, IED 1B2	SubstationComputerDevice 1	Fault Detected		Deterministic Rapid Response Intra-Sub
2.4		IED 1B1	2nd Trip	First IED trips breaker and reports the action. Starts reclosure timer. This message indicates that the SC can now attempt to open a switch for auto-sectionalization.	IED 1B1	SubstationComputerDevice 1	Trip		Deterministic Rapid Response Intra-Sub
2.5		SubstationComputerDevice 1	Auto-sectionalize	Computer determines the correct switch to open based on the fact that the upstream switches reported fault current, while the downstream switches reported no current or voltage. Directs the correct switch to open between reclosures of the breaker.	SubstationComputerDevice 1	IED 1B2	Switch Control (open)	Time constrained. Must occur between 2nd Trip and 2nd Reclose.	Deterministic Rapid Response Intra-Sub

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
2.6	Reclosure timer expires	IED 1B1	Report Upstream Power Restored	Upon expiry of the reclosure timer, first feeder IED recloses the breaker. Reports the action. Power is now restored from the substation to switch 1B1.	IED 1B1	SubstationComputerDevice 1	Switch State (close), Current, Voltage		Deterministic Rapid Response Intra-Sub
3.1	Logic timer expires	SubstationComputerDevice 1	Request Isolation	Computer detects (using a timer) that no fault has occurred since 1B1 reclosed the breaker. Determines that switch 1B3 is the first switch downstream from the fault and should be opened. Requests confirmation from SystemOperator.	SubstationComputerDevice 1	SystemOperator 1	Request (open 1B1)		User Interface
3.2		SystemOperator 1	Confirm Isolation	Tells the SubstationComputerDevice it is permitted to open the first downstream switch (1B3).	SystemOperator 1	SubstationComputerDevice 1	Confirm		User Interface
3.3		SubstationComputerDevice 1	Isolate Fault	Requests that the first downstream switch (1B3) open.	SubstationComputerDevice 1	IED 1B3	Switch Control (open)		Deterministic Rapid Response Intra-Sub

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
3.4		IED 1B3	Report Isolation Complete	The IED controlling the first downstream switch reports that the switch is open.	IED 1B3	SubstationComputerDevice 1	Switch State (open)		Deterministic Rapid Response Intra-Sub
4.1		SubstationComputerDevice 1	Request Load Split	Computer determines from the Current and Voltage information stored prior to the fault that service cannot be restored from a single source. Determines which switch to operate (1B4) and requests confirmation from the SystemOperator.	SubstationComputerDevice 1	SystemOperator 1	Request (open 1B4)		User Interface
4.2		SystemOperator 1	Confirm Load Split	SystemOperator confirms that the Computer may open the switch to split the load (1B4)	SystemOperator 1	SubstationComputerDevice 1	Confirm		User Interface
4.3		SubstationComputerDevice 1	Split Load	Computer opens the switch to split the load (1B4)	SubstationComputerDevice 1	IED 1B4	Switch Control (open)		Deterministic Rapid Response Intra-Sub
4.4		IED 1B4	Report Load Split Complete	IED (1B4) reports that the switch is open and the load is split.	IED 1B4	SubstationComputerDevice 1, SubstationComputerDevice 2	Switch State		Deterministic Rapid Response Intra-Sub

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
5.1		SubstationComputerDevice 1	Request Local Restoration	Computer determines that half the load can be restored by closing the local normally open switch (1C), and requests permission from operator.	SubstationComputerDevice 1	SystemOperator 1	Request (close 1C)		User Interface
5.2		SystemOperator 1	Confirm Local Restoration	SystemOperator confirms that the Computer may close the normally open switch (1C)	SystemOperator 1	SubstationComputerDevice 1	Confirm		User Interface
5.3		SubstationComputerDevice 1	Restore from Local Source	Computer closes the switch to restore power from the local source (1C).	SubstationComputerDevice 1	IED 1C	Switch Control (close)		Deterministic Rapid Response Intra-Sub
5.4		IED 1B4	Local Restoration Complete	IED (1C) reports that the switch is closed and current is restored to half the load.	IED 1B4	SubstationComputerDevice 1, SubstationComputerDevice 2	Switch State (close), Current		Deterministic Rapid Response Intra-Sub
6.1		SubstationComputerDevice 1	Request Inter-Utility Restoration	Computer determines that the other half of the load can be restored by closing the inter-utility switch (1Y), and requests permission from operator.	SubstationComputerDevice 1	SystemOperator 1	Request (close 1Y)		User Interface

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
6.2		SystemOperator 1	Request Linking Utilities	SystemOperator 1 verifies Computer 1's request and forwards it to SystemOperator 2 at the other utility.	SystemOperator 1	SystemOperator 2	Request (close 1Y)		User Interface
6.3		SystemOperator 2	Confirm Linking Utilities	SystemOperator 2 verifies the request and gives SystemOperator 1 permission to proceed.	SystemOperator 2	SystemOperator 1	Confirm		User Interface
6.4		SystemOperator 1	Confirm Inter-Utility Restoration	SystemOperator confirms that the Computer may close the normally open inter-utility switch (1Y)	SystemOperator 1	SubstationComputerDevice 1	Confirm		User Interface
6.5		SubstationComputerDevice 1	Restore from Inter-Utility Source	Computer closes the switch to restore power from the other utility source (1Y).	SubstationComputerDevice 1	IED 1Y	Switch Control (close)		Deterministic Rapid Response Intra-Sub
6.6		IED 1Y	Inter-Utility Restoration Complete	IED (1Y) reports that the switch is closed and current is restored to the remaining load.	IED 1Y	SubstationComputerDevice 1, SubstationComputerDevice 2	Switch State (close), Current		Deterministic Rapid Response Intra-Sub

2.1.3 Steps – Alternative / Exception Sequences

Describe any alternative or exception sequences that may be required that deviate from the normal course of activities. Note instructions are found in previous table.

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments

2.1.4 Post-conditions and Significant Results

Describe conditions that must exist at the conclusion of the Function. Identify significant items similar to that in the preconditions section.

Describe any significant results from the Function

Actor/Activity	***Post-conditions Description and Results***
System	No faults remaining, service restored to all but the faulted section.

2.2 Architectural Issues in Interactions

Elaborate on all architectural issues in each of the steps outlined in each of the sequences above. Reference the Step by number.

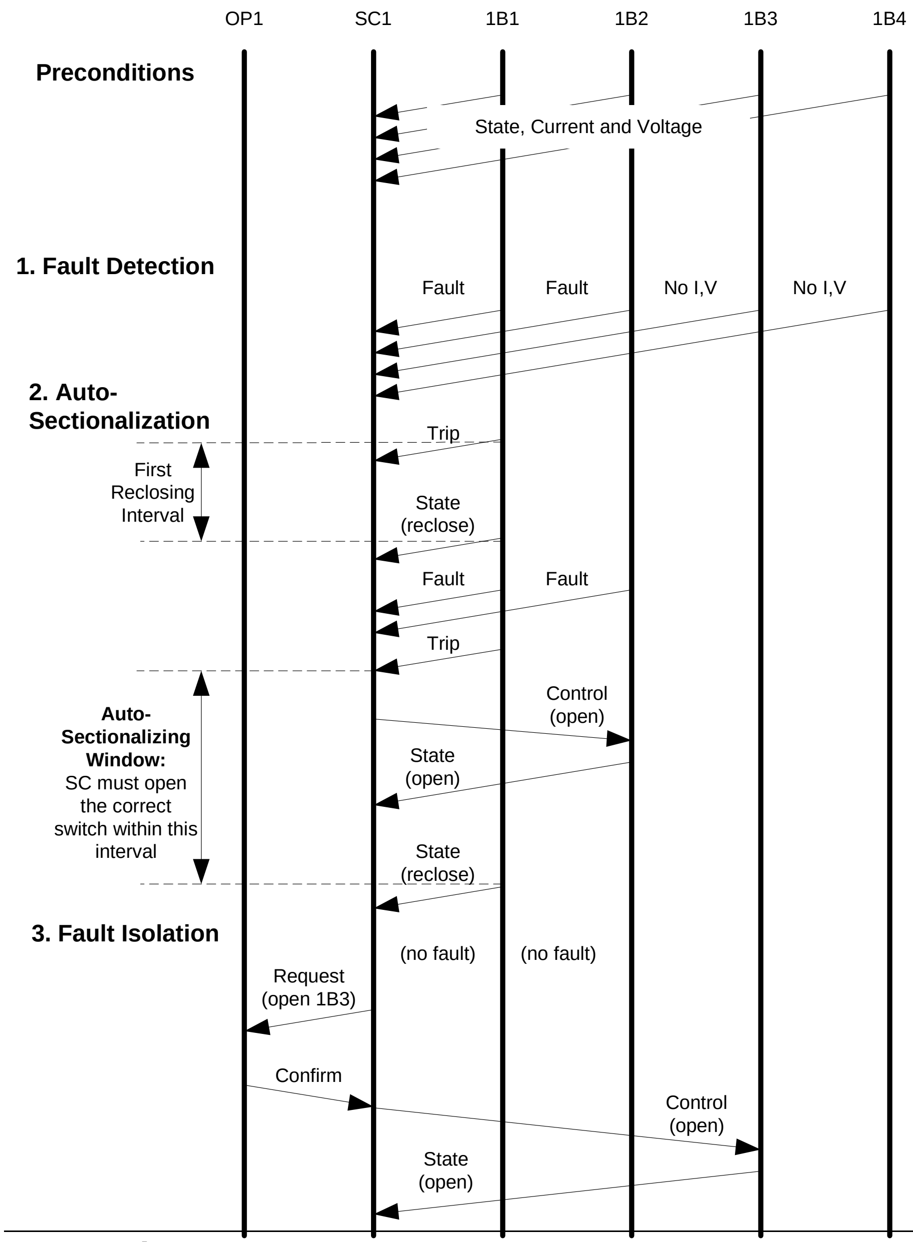
Microsoft Excel Worksheet

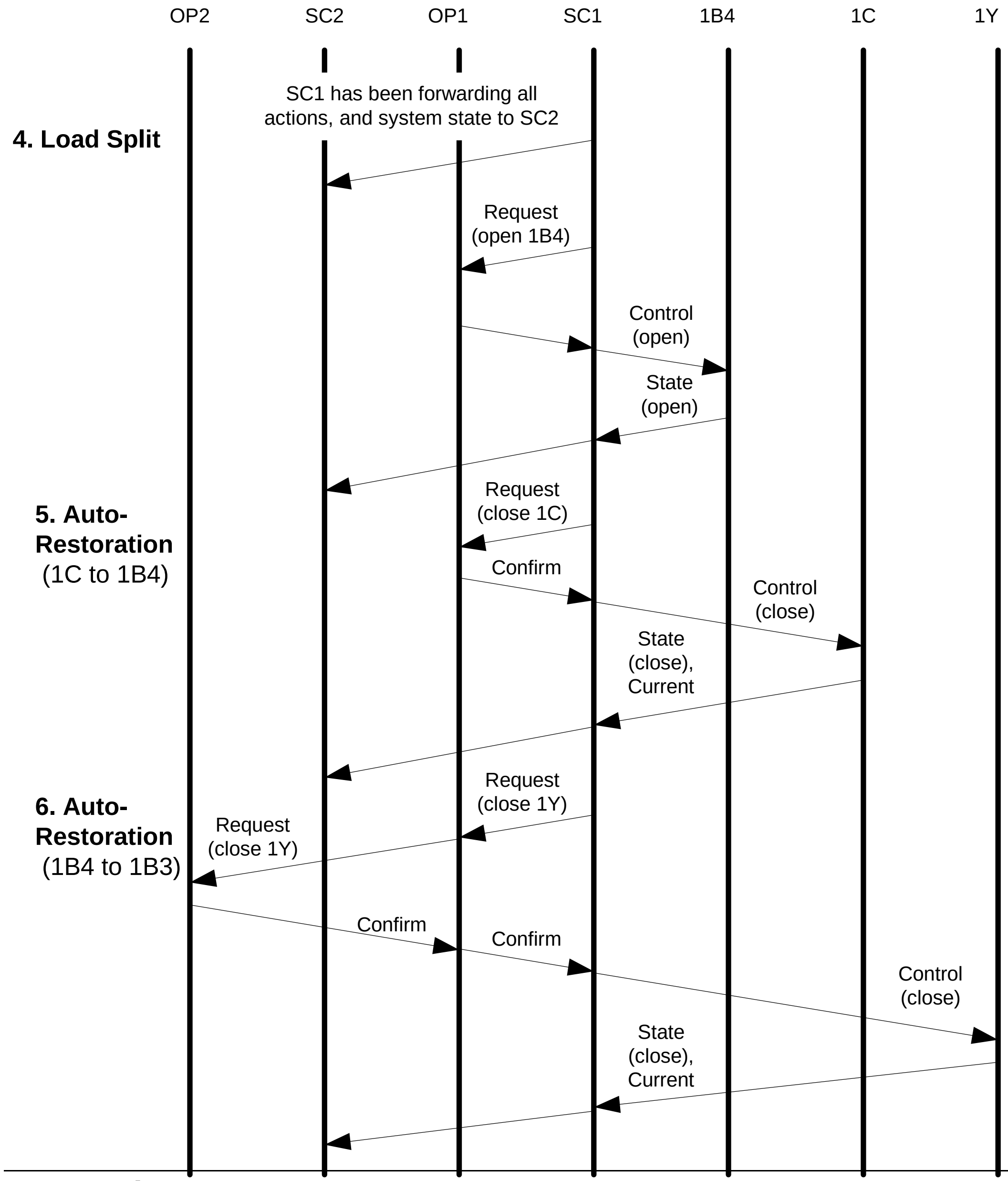
2.3 Diagram

For clarification, draw (by hand, by Power Point, by UML diagram) the interactions, identifying the Steps where possible.

The following two diagrams illustrate the steps that are described in section 2.1. These diagrams show the message flow. Refer to the Narrative for a text description and diagrams showing the behavior of the physical system.

The scenario shows the “high-speed communications” option described in the Narrative.


OP1
SC1
1B1
1B2
1B3
1B4
Preconditions
State, Current and Voltage
1. Fault Detection
Fault
Fault
No I,V
No I,V
2. Auto-Sectionalization
Trip
First Reclosing Interval
State (reclose)
Fault
Fault
Trip
Control (open)
Auto-Sectionalizing Window: SC must open the correct switch within this interval
State (open)
State (reclose)
3. Fault Isolation
(no fault)
(no fault)
Request (open 1B3)
Confirm
Control (open)
State (open)


OP2
SC2
OP1
SC1
1B4
1C
1Y
SC1 has been forwarding all actions, and system state to SC2
4. Load Split
Request (open 1B4)
Control (open)
State (open)
5. Auto-Restoration (1C to 1B4)
Request (close 1C)
Confirm
Control (close)
State (close), Current
6. Auto-Restoration (1B4 to 1B3)
Request (close 1Y)
Request (close 1Y)
Confirm
Confirm
Control (close)
State (close), Current

3 Auxiliary Issues

3.1 References and contacts

Documents and individuals or organizations used as background to the function described; other functions referenced by this function, or acting as "sub" functions; or other documentation that clarifies the requirements or activities described. All prior work (intellectual property of the company or individual) or proprietary (non-publicly available) work must be so noted.

ID	Title or contact	Reference or contact information
[1]	Danny Wong	GE Power Systems
[2]	Jim McGhee	GE Power Systems

3.2 Action Item List

As the function is developed, identify issues that still need clarification, resolution, or other notice taken of them. This can act as an Action Item list.

ID	Description	Status
[1]		
[2]		

3.3 Revision History

For reference and tracking purposes, indicate who worked on describing this function, and what aspect they undertook.

No	Date	Author	Description
0.			

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