

Wide-Area Monitoring And Control – Automated Control Functions

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

Name of Function

Wide Area Monitoring and Control – Automated Control Functions

1.2 Function ID

IECSA identification number of the function

T-4,T-4.1,T-4.2,T-4.3,T-4.18,T-4.19,T-6.5,T-6.10,T-6.21,D-5,L-2.2.1,L-2.2.2,L-2.4,L-3.2,L-3.4,L-3.6,L-3.8,C-9.4

1.3 Brief Description

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

WAMACS Automated Control describes a set of functions that are typically automated within a substation, but are not directly associated with protection, fault handling, or equipment maintenance. In general, they serve to optimize the operation of the power system and ensure its safe operation by preventing manually generated faults. These functions include:

- Changing transformer taps to regulate system voltage
- Switching capacitor banks or shunts in and out of the system to control voltage and reactive load
- Interlocking of controls to prevent unsafe operation
- Sequencing controls to ensure safe operation
- Load balancing of feeders and transmission lines to reduce system wear and resistive losses

- Restoring service quickly in the event of a fault, with or without operator confirmation

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.

The functions described in this use case were traditionally performed by individual devices acting alone. When implemented this way, they did not have any effect on the communications system. However, in the last five to seven years, these functions have been distributed across the substation. That is, the software logic controlling the function now often resides on a different device than the one which provides the inputs or outputs to the process.

This change has taken place because the use of substation LANs has made it economical to place Intelligent Electronic Devices (IEDs) close to the equipment they are monitoring and controlling. Logic has therefore either been centralized, with a single Substation Computer using the IEDs as remote controllers, or it has been distributed among the IEDs themselves. In either case, the communications system has now become part of the automation functions.

1.4.1 Voltage Regulation using Tap Changers

In voltage regulation, the automation system ensures a constant voltage on the substation bus by adjusting the tap of one or more transformers. A monitoring IED provides a voltage value to the Substation Computer, which has been programmed with threshold and hysteresis logic. The IED is usually monitoring the bus side of a transformer. In more complex situations, IEDs may monitor multiple voltages throughout the station and pass them all to the Substation Computer as input to the logic. When the logic indicates that the bus voltage must be adjusted, the Substation Computer issues a control operation to the IED connected to the transformer tap. This will change the monitored voltage, which will be fed back through the logic.

The voltage control logic typically has a pre-programmed qualification delay in the tens of seconds – adjusting the tap causes wear on the equipment, so adjustments should not be made lightly. Therefore, an appropriate update time for the monitored voltage is on the order of one-half second to one second. Because of the wear on the transformer and tap, and the impact on the rest of the system if adjusted wildly, tap raise/lower operations are typically performed with select-before-operate logic. Redundancy and reliability of the communications path is important.

1.4.2 Volt/VAR Regulation using Capacitor or Shunt Control

In capacitor bank control, the automation system optimizes the voltage and inductive load on a line or bus by connecting or disconnecting one or more capacitor banks. It prevents the imaginary part of the load from becoming too large, reducing voltage and the efficiency of the system. The banks may be widely located across the power system, or within the substation. There are many different logic algorithms for performing capacitor bank control. The simplest is calendar or time of day control, in which the load on the power system is not even monitored. The logic simply assumes that the inductive load will be higher at certain times of the day or year. In areas where inductive load is largely caused by air conditioning, logic may switch based on ambient temperature. Some algorithms monitor voltage only and switch when it passes certain thresholds. More sophisticated algorithms monitor both current and voltage and switch based on either the calculated power factor or directly on the calculated inductive load (VARs). There are typically hysteresis settings on such logic to prevent frequent switching. Shunt control occurs under similar conditions, but with the addition or removal of inductive loads.

In distributed Volt/VAR control, one IED controls one capacitor bank on a given line, and each IED makes switching decisions individually. In centralized Volt/VAR control, each IED reports monitored values back to a Substation Computer. The Substation Computer may make switching decisions based on averages or groupings of voltages. When it decides a switch is necessary, it sends a control message to the appropriate IED, which may or may not be the device reporting the controlled measurements.

The hysteresis in some Volt/VAR algorithms may often be in hours, so communication delays in tens of seconds are easily acceptable. It is fairly common to broadcast capacitor bank control messages, without any select-before-operate logic, since the effect of any given control is usually small. When capacitor banks are located remotely, pagers have sometimes been used as a communications media – one number to switch the bank in, one to disconnect it.

1.4.3 Interlocking

Interlocking prevents unsafe operation of the various switches and breakers within a substation. When an Operator or software application attempts to operate a control, the automation system evaluates the state of the entire system and may reject the control request based on pre-programmed logic. This logic corresponds directly to the topology and interconnection of the substation. Simpler substations may have little or no interlocking. The most complex logic is associated with complex transformer and bus redundancy systems.

For instance, an operator will close an earthing switch on a section of the bus to ground it prior to permitting maintenance on the equipment. However, the operator may not be aware that the bus section is still live due to an interconnection with another bus section or a feeder fed by another bus section. The automation system must prevent a fault by rejecting the Operator's request.

Interlocking is most reliably and efficiently performed by the device that must perform the requested operation. In the past, it may have been performed by the substation GUI or SCADA master station, when those were the only locations that could perform switching. It is still often

performed by a Substation Computer or Data Concentrator which serves as a clearinghouse for all control operations to the substation. This centralized logic mechanism is still used, especially because deregulation has increased the number of master stations that require access to the substation.

However, more and more frequently, interlocking is performed by logic on the IEDs themselves, operating on data distributed by peer-to-peer communications between the devices. This peer-to-peer communications has been made possible by the introduction of the substation LAN. Performing interlocking at the IED permits the same logic and performance to be in effect regardless of whether the control request originates at a remote site, at a substation GUI, at the control panel of the IED, or even a manual panel switch.

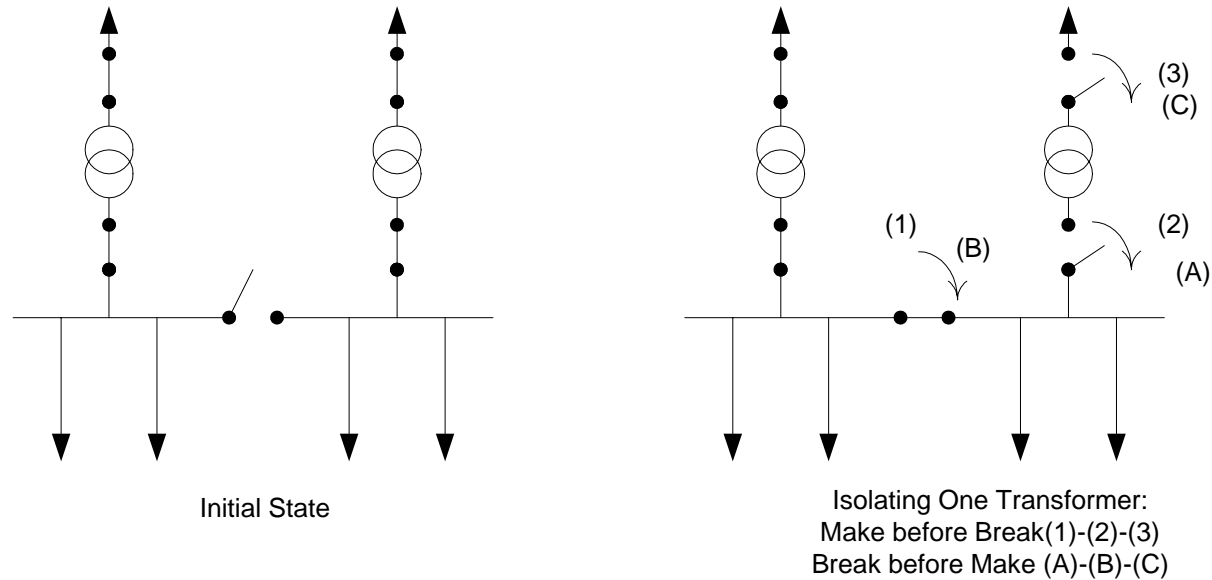
In an ideal system, the state information required to perform interlocking would be updated simultaneously throughout the system. Any delay provides a window in which a control could be mis-operated. However, in practice, it is sufficient to update the state of the system in less than a second or two. This interval represents the typical time between the moment an Operator checks the state of the system on a GUI or display panel, and the moment the Operator makes the control request. As more automation applications are deployed in the substation, human reaction time will become less of a factor, and the demands on interlocking will increase. Today, a challenging interlocking requirement for an advanced substation is less than 200 milliseconds between updates.

The control itself is typically issued with select-before-operate logic. The distribution of state information for interlocking may be broadcast or multicast. Redundancy and reliability is extremely important.

1.4.4 Sequenced Controls

While interlocking is intended to prevent Operator-initiated faults by rejecting invalid controls, sequenced controls automate some portion of the Operator's tasks to eliminate the possibility of an invalid control ever being issued.

For example, consider a substation with two transformers and a normally open switch between the two bus sections connected to each transformer. There are two different philosophies that an Operator may employ to take one of the transformers out of service. In "make before break", the Operator should (1) connect the two buses, (2) disconnect the transformer from the bus, and (3) disconnect the transformer from the upstream transmission line. This method ensures there will be no outage of service. In "break before make", however, the Operator should (A) disconnect the transformer, then (B) quickly connect the bus and then (C) disconnect the transmission line. This results in an outage, but prevents side effects resulting from mis-matched transformers sharing the same bus.



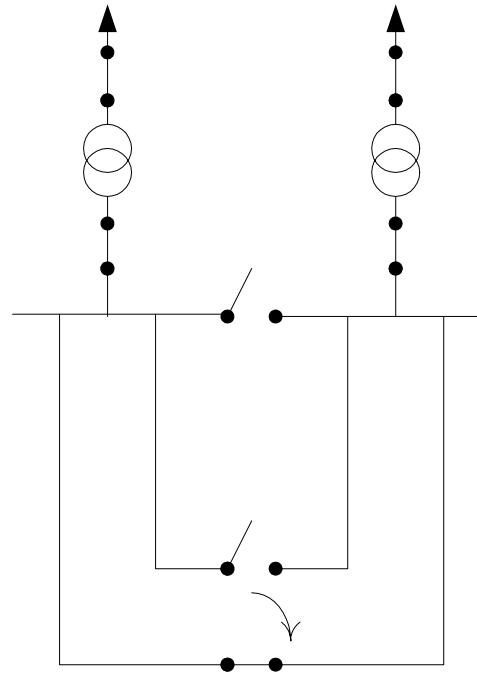
In a sequenced control, the Operator simply requests the isolation of the transformer, and the automation system performs the controls in the sequence required by the utility. The Operator is not permitted to perform any other sequence. In the “break before make” case above, it also ensures that the resulting outage is as small as possible, because the automation system can perform the sequence faster than a human.

The speed of a sequenced control is related to the components involved in the sequence. For instance, the logic may need to wait for motorized switches to connect or disconnect before proceeding with the next control in the sequence. In a “break before make” sequence as described above, however, the length of the outage must be minimized and a value of less than half a second is typically desired. All sequenced controls are typically service-affecting and are therefore executed with select-before-operate logic.

1.4.5 Load Balancing

Load balancing is typically a distribution operation, performed between two transformers within a substation, but may also be performed in transmission systems between substations. In the distribution case, two feeders serviced by separate transformers are connected at their remote ends by a normally open switch. A pole-top IED controls the switch. Other IEDs monitor load on the line. The IEDs report the state and load of the system to a Substation Computer. The Substation Computer detects the condition when one transformer is heavily loaded and the other has excess capacity, and sends a message to the pole-top IED to close the switch. Now, instead of one line loaded at 90% and the other at 25%, both

may be loaded at 50%. Since resistive losses vary with the square of the current, this action improves the efficiency of the power system and reduces wear on equipment. In transmission systems, two substations having lines feeding the same third substation may share load. This type of logic is typically centralized, not distributed.

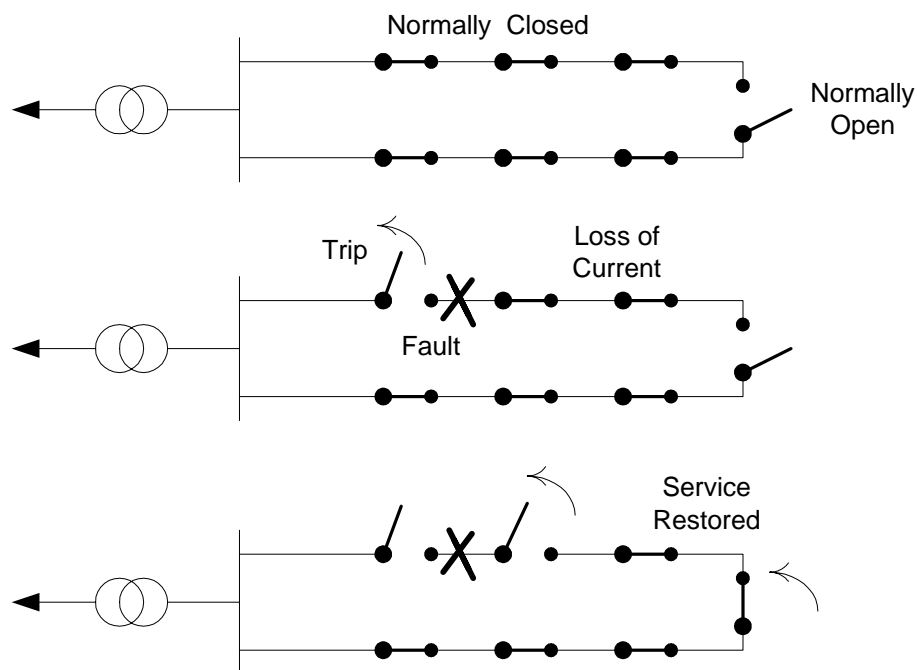


As with tap changing, load balancing is not an action that is typically performed lightly. Qualification times for the logic may be measured in minutes or even hours. Therefore, update times and control transmission times may be measured in seconds. In distribution operations, this is fortunate because IEDs controlling the switches may be remote and only reached via slow links. Some utilities may prefer that the process not be completely automated, and that the automation system request confirmation from the Operator before taking action. Reliability of the data is important and redundant links may be used.

1.4.6 Automated Service Restoration

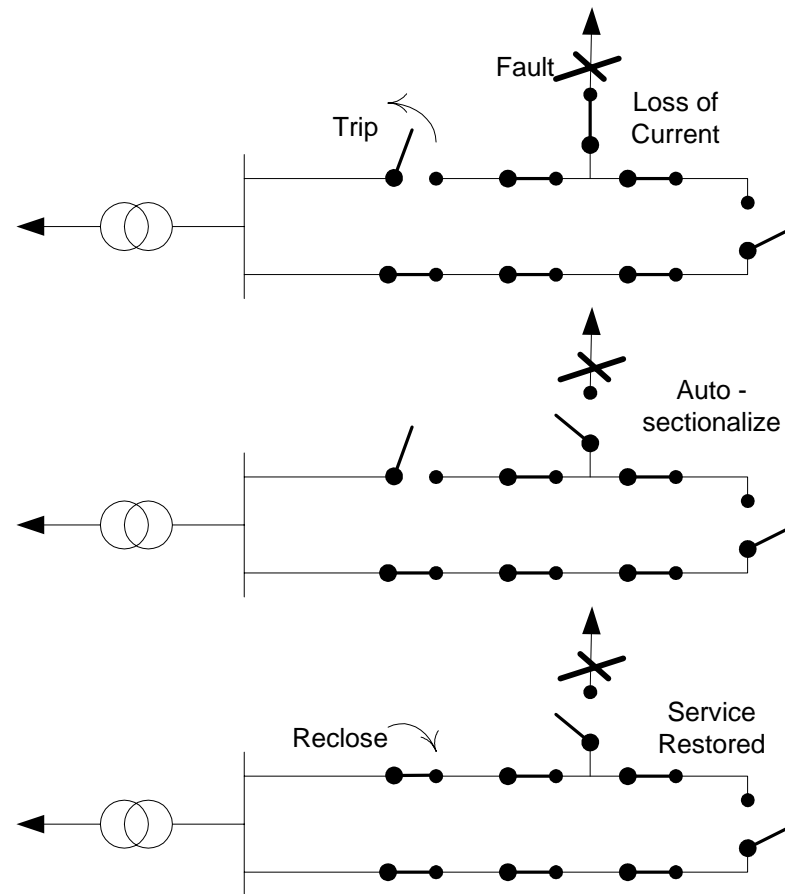
Automated Service Restoration is typically a distribution operation, but may be performed in transmission systems when “loops” are possible between substations. In the distribution case, two feeders are connected at their remote ends by a normally open switch. Several other switch /

breaker combinations are located at other points along the feeders. All the switches and breakers are monitored by IEDs. When a fault occurs, the IEDs on the upstream side of the fault trips its breaker. It notifies the Substation Computer of its action. The IED on the downstream side of the fault notifies the Substation Computer of the loss of current and estimates the direction of the fault. Based on that information and pre-configured logic, the Substation Computer recommends to the Operator that the breaker of the downstream IED should be opened and the normally open switch should be closed. The Operator typically directs the Substation Computer to do so, and the Substation Computer forwards the decision to the IEDs. When the IEDs perform the operations, power is restored to all portions of the feeders except the section in which the fault occurred. The more break points there are in the feeders, the fewer customers will be affected by a given fault.



Time is of the essence in service restoration, but utilities typically require an Operator approve the decision of the system, so the human Operator is usually the slowest link in the system. Communications times may be measured in seconds. The breaker tripping is done by an individual IED without need for communications.

An alternative scenario occurs if the fault is not on the main feeder but on a lateral. In this case, the fault causes the protection IED at the substation to trip and attempt reclosure. While the current is zero between reclosure attempts, the IED nearest the fault opens its switch to clear the fault. This is called “auto-sectionalization”. Then, when the next reclosure occurs, service is restored to all subscribers except those on the lateral. In this case, there is no effect on the communications system other than to monitor that the events occurred.



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.

<i>Grouping (Community)'</i>		<i>Group Description</i>
<i>Actor Name</i>	<i>Actor Type (person, device, system etc.)</i>	<i>Actor Description</i>
SubstationComputerDevice	Device	Central location for automation logic in the substation. May have its own user interface, or communicate with the SystemOperator through a separate GUI.
IED	Device	Monitors and controls portions of the substation, feeders and transmission lines under direction of the SubstationComputerDevice
AutomationSystem	System	Optimizes the operation of the power system. Consists of the SystemOperator, SubstationComputerDevice, and IEDs.
SystemOperator	Person	Approves or rejects actions recommended by the SubstationComputerDevice.

Replicate this table for each logic group.

1.6 Information exchanged

Describe any information exchanged in this template.

<i>Information Object Name</i>	<i>Information Object Description</i>
Timestamp	A data event such as a change of state is associated with a timestamp that indicates when the change of state occurred relative to the system clock. There is often a 1 ms accuracy requirement that specifies that the timestamp must be within 1 millisecond of the actual event. The time stamp is applied at the device that is responsible for processing the field point for which the event occurred. The timestamp is then associated with the change of state event that is reported to the other devices in the system. These time stamped events can occur on the IED or the Data Concentrator if it is equipped with equipment to monitor field devices.
Point Number	The unique index of the point that is associated with the state or value that is currently of interest and is one of the points being monitored in the system. This number is a certain point in the IED, which becomes a different point in the Data Concentrator database and in turn becomes a different point number in the protocol that communicates with the GUI. There could be several mapping stages at each device the point goes through.
Voltage, Current	Analog values used in the system are often a twelve-bit or sixteen-bit integer that must be scaled for display in engineering units. The information includes: a point number, the quality of the point, and the value. It may or may not include a millisecond timestamp if the value is associated with a change event. A voltage would be scaled to engineering units of V or kV and a current in A. This is usually converted in the GUI which is a PC platform that supports floating point easily. This preserves the resolution in the raw data coming through the protocol. Point Number + Analog Value + Quality + Timestamp (optional)
Switch State	Digital Input with value Open or Closed, 0 or 1, Trip or Closed, Off or On, Normal or Alarm, etc. The change of state of a field input such as a switch. Includes: a point number, the quality of the point (online/offline or valid/invalid), the new state, and the time the state changed which is typically accurate to millisecond resolution. If the state of the input is Trip it represents a particular type of state change that indicates through its point number that a certain breaker has tripped and is now open. Includes all the same data as any state change but state is unique to the application. Point Number + Digital Value + Quality + Timestamp
Command	A control request is used to initiate a digital field operation such as close a breaker or switch. The operation required is defined in the protocol and can be a Trip or Close, Raise or Lower for a digital control or Open or Close or Raise or Lower for an analog event. The operator selects the operation type when the request is setup.
Duration or Count	The time in milliseconds that the coil of a relay will be energized in the device that is required to perform the requested command. The time is usually determined by how long it takes to pick up the field operation which seals itself in for the full duration of the operation. Most digital controls are short pulses between 500 and 1000 ms. Sometimes the operator enters the desired duration and sometimes it is pre configured in the device.
Control Request	Point Number + Command. A request initiated by the SystemOperator to the Station Computer, requesting that a

<i>Information Object Name</i>	<i>Information Object Description</i>
	particular control be operated. May be a single control or the start of a sequenced control.
Automated Control Request	Point Number + Command. A control request initiated by the SubstationComputerDevice to the SystemOperator in the form of a change of state on a data point or a GUI dialog box that pops up on the operator's screen. The animation will notify the operator that a request is pending and must be confirmed.
Confirm	The SystemOperator confirms (or rejects) an Automated Control Request from the SubstationComputerDevice. The SystemOperator typically clicks 'ok' on a dialogue box after performing any operational procedures that are required for ensuring the automated control can execute.
Control	Point Number + Command. The message sent from the SubstationComputerDevice to an IED to open or close a switch.
Tap Change Control	Point Number + Command + Duration or Count. The message sent from the SubstationComputerDevice to an IED to raise or lower a transformer tap.
Control Status	The SubstationComputerDevice indicates the success or failure of a Control Request to the SystemOperator as a console GUI message, dialog box, and/or an alarm indication.

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.

<i>Activity/Service Name</i>	<i>Activities/Services Provided</i>
Optimize Substation Voltage	Raise or lower substation transformer taps
Reduce Reactive Load	Switch capacitor banks and shunts in or out of the power system
Prevent Unsafe Operations	Reject controls that would cause faults or other unsafe procedures
Perform Sequenced Controls	Perform several controls in an atomic sequence to reduce or eliminate outages
Balance Load	Connect two feeders or transmission lines together to reduce the load on equipment
Restore Service	Isolate faulted segments of feeders or transmission lines and redirect power from nearby sources to restore service

<i>Activity/Service Name</i>	<i>Activities/Services Provided</i>
Select/Execute Logic	Operation of a digital output by “I tell you twice” logic to prevent misoperation.

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.

<i>Contract/Regulation</i>	<i>Impact of Contract/Regulation on Function</i>

<i>Policy</i>	<i>From Actor</i>	<i>May</i>	<i>Shall Not</i>	<i>Shall</i>	<i>Description (verb)</i>	<i>To Actor</i>
Unsafe Operation	AutomationSystem		X		Permit manually-initiated faults	SystemOperator
Reactive Load	AutomationSystem			X	Maintain Power Factor or VARs within preset limits	SystemOperator
Maximum Load	AutomationSystem			X	Maintain current on a particular feeder or transmission line below preset limits	SystemOperator
Substation Voltage	AutomationSystem			X	Maintain voltage within the substation within preset limits	SystemOperator
Break Before Make Outage	AutomationSystem			X	Minimize the length of outage required by “break before make” operations	SystemOperator
Service Affected	AutomationSystem			X	Minimize the number of subscribers affected by a fault	SystemOperator

<i>Constraint</i>	<i>Type</i>	<i>Description</i>	<i>Applies to</i>

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

Name of this sequence.

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'.

<i>Actor/System/Information/Contract</i>	<i>Preconditions or Assumptions</i>

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
#	<i>Triggering event? Identify the name of the event.¹</i>	<i>What other actors are primarily responsible for the Process/Activity? Actors are defined in section 1.5.</i>	<i>Label that would appear in a process diagram. Use action verbs when naming activity.</i>	<i>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.</i>	<i>What other actors are primarily responsible for Producing the information? Actors are defined in section 1.5.</i>	<i>What other actors are primarily responsible for Receiving the information? Actors are defined in section 1.5. (Note – May leave blank if same as Primary Actor)</i>	<i>Name of the information object. Information objects are defined in section 1.6</i>	<i>Elaborate architectural issues using attached spreadsheet. Use this column to elaborate details that aren't captured in the spreadsheet.</i>	<i>Reference the applicable IECSA Environment containing this data exchange. Only one environment per step.</i>

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
1.1	Voltage Change	IEDs	Change in Voltage	<p>VOLTAGE REGULATION. IED identifies that the voltage has exceeded the deadband to be recognized as a change and notifies the SubstationComputerDevice.</p> <p>May be performed by one or more IEDs depending on the logic being used. SubstationComputerDevice maps the point number into its database, stores the value, and runs the voltage control logic. Typically starts a qualification timer to avoid rapid and frequent tap changes.</p>	IEDs	SubstationComputerDevice	Voltage	Scaling typically configured at SC.	High security 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
1.2	Qualification Timeout	SubstationComputerDevice	Tap Change	<p>SubstationComputerDevice identifies that the voltage change(s) received from the IED(s) represent a significant change and require action. Issues a command to the IED.</p> <p>IED performs the tap change through local I/O. Causes voltage change (1.1) and cycle repeats.</p>	SubstationComputerDevice	IED	Tap Change Control	<p>Raise is often issued to a different point than the Lower.</p> <p>Some tap changers require multiple pulses, other varying durations.</p>	High security 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
2.1	Load Change	IED	Change in Load	<p>VOLT/VAR REGULATION. IED identifies that the voltage and/or current has exceeded the deadband to be recognized as a change and notifies the SubstationComputerDevice.</p> <p>May be performed by one or more IEDs depending on the logic being used. SubstationComputerDevice maps the point number into its database, stores the value, and runs the Volt/VAR control logic. Starts a qualification timer if appropriate.</p> <p>If extremely simple control logic is being used (e.g. calendar, time-of-day, this step may be omitted).</p>	IED	SubstationComputerDevice	Voltage, Current	Scaling typically configured at SC.	High security 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
2.2	Qualification Timeout	SubstationComputerDevice	Adjust Reactive Load	<p>SubstationComputerDevice decides that it is time to adjust the load and issues a control to the appropriate IED. Applies qualification times and hysteresis algorithms to avoid many rapid adjustments.</p> <p>May not be the same IED as last reported a Load Change.</p> <p>Adjustment usually causes a Load Change (2.1) and cycle repeats.</p>	SubstationComputerDevice	IED	Control		High security Intra-sub
3.1	System State Change	IED	Change of System State	<p>INTERLOCKING. IED detects a change in a switch or breaker that it is monitoring and transmits the state change to the device implementing the logic, either the SubstationComputerDevice or one or more peer IEDs.</p> <p>SubstationComputerDevice or peer IED maps the point number into its database, stores the value, and thus updates its current "picture" of the system state.</p>	IED	IED or SubstationComputerDevice	Switch State, Voltage, Current	Logic may be centralized at SubstationComputerDevice or distributed among IEDs (peer-to-peer)	High security 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
3.2	Switch Request	SystemOperator	Request Switch	SystemOperator requests that a particular switch or breaker be opened or closed. Device receiving the command runs interlocking logic and either denies (3.3) or accepts (3.4) the request.	SystemOperator	IED or SubstationComputerDevice	Control Request	May be issued at master station, SubstationComputerDevice, or IED.	Intra-control center
3.3		IED or SubstationComputerDevice	Deny Request	Device performing the interlocking logic rejects the attempt as being unsafe.	IED or SubstationComputerDevice	SystemOperator	Control Status	May take place during either Select or Execute phase of the request.	Intra-control center
4.1	Sequenced Control Request	SystemOperator	Request Sequenced Control	SEQUENCED CONTROL. SystemOperator requests a sequence to be performed.	SystemOperator	SubstationComputerDevice	Control Request		Intra-control center
4.2		SubstationComputerDevice	Send Control	SubstationComputerDevice runs the sequence logic and issues the next control to an IED.	SubstationComputerDevice	IED	Control	Timing between successive controls may be constrained in order to prevent outages.	High security 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
4.3	Feedback	IED	Send Feedback	<p>IED provides feedback about whether the last control was successful.</p> <p>SubstationComputerDevice maps the point number into its database, stores the value, and runs the sequence logic. Typically logs the state change and its time.</p> <p>If feedback was successful, SubstationComputerDevice initiates next control (4.2). If not, if the feedback timed out, or if this was the last control, may terminate sequence (4.4).</p>	IED	SubstationComputerDevice	Switch State	Feedback must come from actual I/O in order for logic to rely on it.	High security Intra-Sub
4.4	Sequence Complete	SubstationComputerDevice	Terminate Sequence	SubstationComputerDevice stops the sequence logic and indicates to SystemOperator the status of the sequence.	SubstationComputerDevice	SystemOperator	Control Status		Intra-control center

#	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	Load Change	IED(s)	Change in Load	<p>LOAD BALANCING. IED identifies that the current has exceeded the deadband to be recognized as a change and notifies the SubstationComputerDevice.</p> <p>May be performed by one or more IEDs depending on the logic being used. SubstationComputerDevice maps the point number into its database, stores the value, and runs the load balancing control logic.</p>	IED(s)	SubstationComputerDevice	Current, Voltage	Scaling typically configured at SC.	High security Intra-Sub
5.2	Request to Connect Feeders / Lines	SubstationComputerDevice	Request Connection to Feeders / Lines	<p>SubstationComputerDevice determines that load has exceeded acceptable thresholds and that conditions are met to perform balancing.</p> <p>Requests that SystemOperator connect a particular two feeders or lines.</p> <p>SystemOperator either confirms the operation (5.3) or does nothing, and load continues to increase (5.1).</p>	SubstationComputerDevice	SystemOperator	Automated Control Request		Intra-control center

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
5.3		SystemOperator	Confirm Request	SystemOperator issues control accepting the request.	SystemOperator	SubstationComputerDevice	Confirm		Intra-control center
5.4		SubstationComputerDevice	Balance Load	SubstationComputerDevice issues a control to connect the two feeders or lines. Load will readjust and cycle repeats (5.1).	SubstationComputerDevice	IED	Control		High security Intra-Sub
6.1	Fault	Upstream IED	Breaker Trip	AUTOMATIC SERVICE RESTORATION. IED detects fault and trips breaker. Notifies SubstationComputerDevice of the trip, and (through the point number) the direction and distance to the fault.	Upstream IED	SubstationComputerDevice	Trip	IED is typically on pole-top and may be reached by slow links.	High security Intra-Sub
6.2	Loss of Current	Downstream IEDs	Report Loss of Current	IEDs detect loss of current. Notify SubstationComputerDevice of the event and the suspected direction and distance of the fault.	Downstream IEDs	SubstationComputerDevice	No Current Detected, No Voltage Detected	IEDs running on battery power	High security 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
6.3		SubstationComputerDevice	Request Restoration	SubstationComputerDevice runs auto-restoration logic and determines which switch should open. Requests permission to open that switch and close the normally-open switch. SystemOperator will either confirm the request (6.4), or decide to perform some other operation through the SubstationComputerDevice.	SubstationComputerDevice	SystemOperator	Automated Control Request		Intra-control center
6.4		SystemOperator	Confirm Request	SystemOperator tells the SubstationComputerDevice to execute the restoration.	SystemOperator	SubstationComputerDevice	Confirm		Intra-control center
6.5		SubstationComputerDevice	Open Switch	Substation computer performs control to open the downstream switch nearest the fault.	SubstationComputerDevice	Downstream IED	Control		High security Intra-Sub
6.6		SubstationComputerDevice	Close Switch	SubstationComputerDevice performs control to close the normally-open switch.	SubstationComputerDevice	IED controlling normally open switch	Control		High security 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
6.7		IEDs	Send Feedback	IEDs update system state and load to SubstationComputerDevice. SubstationComputerDevice maps data and stores in database.	IEDs	SubstationComputerDevice	Switch State, Current, Voltage		High security 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
3.4		IED or SubstationComputerDevice	Execute Request	Device performing the interlocking logic tells the IED to operate the control request. May be the same IED.	IED or SubstationComputerDevice	IED	Control		High security Intra-Sub
3.5		IED or SubstationComputerDevice	Confirm Request	Device performing the interlocking logic informs the SystemOperator that the request has been successfully performed.	IED or SubstationComputerDevice	SystemOperator	Control Status	May take place during either Select or Execute phase of the request.	Intra-Control Center

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environments
X.1	Fault	Upstream IED	Trip Breaker	IED detects fault and trips breaker. Notifies SubstationComputerDevice of the trip, and (through the point number) the direction and distance to the fault. Starts reclosure timer.	Upstream IED	SubstationComputerDevice	Trip		High security Intra-Sub
X.2		Lateral IED	Report Lateral Switch Open	IED detects the fault and that current is zero. Waits a configured number of reclosure attempts, then opens the switch for the Lateral. Notifies the SubstationComputerDevice.	Lateral IED	SubstationComputerDevice	Switch State		High security Intra-Sub
X.3		Upstream IED	Breaker Reclosed	Upstream IED successfully recloses the breaker and notifies the SubstationComputerDevice that service is restored.	Upstream IED	SubstationComputerDevice	Switch State		High security Intra-Sub

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

<i>Actor/Activity</i>	<i>Post-conditions Description and Results</i>

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.

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]		
[2]		

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.	Oct 17, 2003	GG	Initial version.