Ultra High-speed, Automatic Transfer Scheme for Critical Load Applications

SDFA-ATS
Technical Description

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Siemens Distribution Feeder Automation (SDFA) system is a decentralized, distribution automation (DA) solution where all of the control and switching logic resides in automation controllers installed in distribution network reclosers and switches.

The Siemens Distribution Feeder Automation (SDFA) application suite comprises a number of DA applications and solutions. SDFA-ATS (Automatic Transfer Scheme) is one such application. SDFA-ATS is an ultra high-speed, Automatic Transfer Scheme (ATS) that switches critical loads from primary to alternative power sources in as little as 100 milliseconds.

SDFA-ATS protects critical loads such as medical facilities, fire stations and military installations by automatically transferring power from primary to alternative power sources in the event of a fault. When operations return to normal, the system can be programmed to automatically return the loads to the preferred sources.

Transfer times depend largely on the operational speeds of the communications system and the primary line switching devices. When a Siemens type SDR recloser is used with a fiber optic communication system, transfer times of less than 100 milliseconds are typical. With a WiMAX communications system, transfer times of approximately 200 milliseconds can be achieved.

In its simplest form, the Siemens Distribution Feeder Automation (SDFA) system consists of automation controllers and some form of high-speed, IP-based communications link. SDFA supports brownfield as well as greenfield applications. In brownfield applications, SDFA automation controllers are interoperable with and can be installed in other manufacturers’ switchgear, and are also compatible with existing recloser or feeder protection systems.

SDFA-ATS is available as loose components or as a complete package consisting of a Siemens SDFA automation controller and a Siemens type SDR recloser acting as the primary switch device. This option provides both high-speed transfer capability as well as basic feeder protection.

The system can also be ordered to retrofit existing reclosers, motorized switches and circuit breakers.

Features:
- Rapid operation minimizes outage times
- High-speed transfer (within six cycles)
- Normal transfer (within nine cycles)
- Protection fault supervision
- Auto restoration
- Manual restoration
- Open or closed transition
- Synchronization check
- Non-proprietary, IEC 61850-compliant communications
- DNP3 serial SCADA interface
- Automatic or manual control
- Simulation mode for realistic, off-line configuration, testing and analysis
- Live test mode for on-line performance testing and verification
- Supplied, pre-programmed components lab-tested to ensure proper operation
How SDFA-ATS works

To accomplish source transfers, Siemens SIPROTEC automation controllers govern the operation of automated reclosers situated on each side of the critical load. When a loss-of-source is detected by a controller, the recloser on the faulted side opens while the recloser on the viable side closes to maintain power to the load.

Each controller contains a powerful programmable logic controller (PLC) comprising multiple AND gates that perform switching steps, which when combined, create logical sequences that control the source transfer process.

Sequences can be configured to operate the reclosers in response to local and network conditions. Operating modes, threshold parameters and sequences are pre-programmed using the Windows-based Siemens DIGSI software tool. Thus, the source transfer system offers the flexibility needed to meet a wide variety of operational demands.

Because the automation controllers communicate with each other in a peer-to-peer fashion, they operate autonomously with no need for master control. However, operations can be monitored, altered and controlled through an automation controller operator interface or a SCADA network via an optional DNP3 link.

Loss-of-source detection

Loss-of-source detection is achieved using voltage sensing inputs located within each automation controller. The sensors are connected to voltage dividers situated on the source side of the line, and when a predefined undervoltage condition is detected, the controllers immediately invoke logical sequences to initiate a source transfer process. Loss-of-source detection is supervised by overcurrent fault detectors to ensure that neither fleeting nor downstream faults will cause spurious, unneeded or unwanted source transfers.

Basic topology

The basic SDFA-ATS consists of the component group shown in Fig. 1. One group is required on each side of the critical load. The automation controller manages both recloser and automation functions. Fig. 2 shows a component grouping that includes a separate recloser controller.
separate recloser controller. In this configuration, the automation controller handles only automation tasks. Both configurations use the voltage dividers to provide reference voltages for the loss-of-source detection tasks. A basic component group installation is shown in Fig. 3.

Fig. 4 identifies the primary connections to a Siemens SDR recloser.

When ordered with the type SDR recloser, the controllers are delivered within the recloser control cabinet (Fig. 5). Otherwise, the automation controller and related components are housed in a small, weatherproof cabinet designed for pole mounting.

For reference purposes, reclosers are referred to as being either “own” or “external.” The recloser at which automatic or manual operations are controlled, observed or initiated using its associated controller is known as the own recloser at that controller. The remaining or distant recloser is known as the external recloser.
Configuration options

SDFA-ATS can be delivered complete with Siemens equipment or retrofitted to work with existing reclosers (Fig. 6).

**Option 1:**
**Source transfer + feeder protection, Siemens equipment**

Option 1 provides the source transfer function plus traditional feeder protection using a new Siemens type SDR recloser and a 7SC80 automation and protection controller. Undervoltage time and level parameters for the source transfer function can be set at the controller by the user. For protection functionality, time and level parameters for voltage, current and frequency can also be set. The controller is delivered as part of the SDR recloser control cabinet. The interconnecting cabling shown in the figure is supplied with the system.

**Option 2:**
**Source transfer using Siemens equipment**

Option 2 provides the source transfer function using a new Siemens type SDR recloser, type 7SR224 recloser controller and 7SJ80 automation controller. Undervoltage time and level parameters for the source transfer function can be set at the automation controller by the user. The controllers are delivered as part of the SDR recloser control cabinet. The interconnecting cabling shown in the figure is supplied with the system.

**Option 3:**
**Source transfer using existing recloser equipment**

Option 3 provides the source transfer function using a new Siemens 7SC80 automation controller working in conjunction with an existing recloser and its related controller. Undervoltage time and level parameters for the source transfer function can be set by the user. The automation controller is delivered in a small, weatherproof control cabinet designed for pole mounting. The cable interconnecting the automation controller and existing recloser controller is supplied as part of the system.
System interconnections

The equipment interconnections for configuration option 1 are shown in Fig 7. This setup links a Siemens type SDR recloser to a Siemens 7SC80 automation and protection controller. Fig. 8 shows the same setup with an optional sync check capability for closed transition mode operations.

Fig. 7. System interconnections for configuration option 1, Siemens 7SC80 automation and protection controller linked to a Siemens type SDR recloser.

Fig. 8. System interconnections for configuration option 1 with sync check capability.
Fig. 9 shows the interconnections for configuration options 2 and 3. This setup interconnects a recloser and its associated controller with a Siemens automation controller (a 7SJ80 is shown). Fig. 10 shows the same setup with an optional sync check capability for closed transition mode operations.
Communications

SDFA-ATS employs the IEC 61850 communication protocol for all operational and non-operational data exchange between the automation controllers, and in systems equipped with a SCADA network interface, between the controllers and an Ethernet switching arrangement (Fig. 11). GOOSE messaging is used to obtain maximum communications speed and security.

To maximize system operating speeds, Siemens recommends the use of direct fiber optic cable to interconnect the controllers. It is permissible to use alternative media including metallic cable and wireless links (such as WiMAX and Wi-Fi); however, these approaches could introduce propagation delays and network latencies that degrade system performance. The controllers contain a flexible communication port that can be configured to interface with most standard communication schemes and protocols.

The optional SCADA network interface for configuration option 2 consists of an Ethernet switch and an IEC 61850/DNP3 protocol converter for linking to a SCADA remote terminal unit (RTU) through a simple connection. Options 1 and 3 do not require the Ethernet switching arrangement. To facilitate conversion tasks, a comprehensive mapping file identifying gateway points, input/output types, device names and MMS functional tags for IEC 61850–DNP3 translation is provided.

Power supply

The automation controllers delivered with the SDFA-ATS can be powered by either 115 or 230 Vac at 60 Hz, or by a direct current supply in the range of 60 to 250 volts. However, to provide continuous, reliable power from a battery source, the SDFA-ATS is designed to operate from either 24 or 48 Vdc.

The 7SC80 controller contains a battery monitoring and charging system that can be set up for 24 or 48 Vdc operation. When the controller is used in configuration option 1, the controller monitors and charges the batteries, which are collocated with the controller inside the recloser control cabinet. When used in configuration option 3, the controller can be powered by the existing recloser controller supply, or set up to work with its own batteries included as part of the automation controller equipment cabinet.

For systems using the 7SJ80 automation controller (configuration option 2), the controller is powered by the same battery supply as that feeding the 7SR224 recloser controller. The supply can be set up for either 24 or 48 Vdc operation. The battery monitoring and charging system is supplied as part of the recloser controller.

Fig. 11. System communications showing system configuration options 1 and 2 linked to an optional SCADA network interface. The approach used for option 3 varies according to the communication requirements of the existing recloser equipment.
Operator interface

The human-machine interface (HMI) for the 7SC80 automation controller used in configuration options 1 and 3 is shown in Fig. 12. The interface consists of virtual pushbuttons, labeling, status indicators and an operator display and is accessible via the web through a personal computer. Pushbuttons are operated using a “point-and-click” approach and can be assigned by the utility to perform desired tasks. Control and indicator labeling is automatically generated and displayed at the appropriate locations on the screen.

The HMI allows an operator to supervise, control, and monitor the SDFA-ATS at any point where a personal computer and Web access are available. The status indicators show the functional status of the SDFA-ATS, the automation controller and its related battery supply. The control pushbuttons can be used to open and close the own recloser, apply and release hot line tags, reset lockouts, acknowledge system conditions and alarms, change operating modes, initiate system actions, and disable the controls to prevent accidental operations. The operator display enables monitoring of local line voltage, current and frequency conditions and, in conjunction with the control pushbuttons, allows an operator to select and activate system functions and activities.

When the automation controller is used in conjunction with an existing recloser controller as in the case of configuration option 3, some control functions such as opening and closing the own recloser, applying and removing hot line tags, clearing lockouts and monitoring battery status can be performed by the recloser controller as directed by the utility.

![Operator Display](image)

**Fig. 12.** Web-based, virtual operator interface for the 7SC80 automation controller as viewed on a personal computer screen
The HMI for the 7SJ80 automation controller used in configuration option 2 is shown in Fig. 13. The interface consists of front-panel pushbuttons and a keypad, status indicators and a backlit operator display that allow an operator to supervise, control and monitor the SDFA-ATS at the recloser.

The status indicators show the functional status of the SDFA-ATS and the automation controller. The control pushbuttons can be used to open and close the own recloser, acknowledge system conditions and alarms, change operating modes and initiate system actions. The operator display enables monitoring of local line voltage, current and frequency conditions and, in conjunction with the control pushbuttons, allows an operator to select and activate system functions and activities.

Because the automation controller is used in conjunction with a recloser controller, some control functions such as opening and closing the own recloser, applying and removing hot line tags, clearing lockouts and monitoring battery health can be performed by the recloser controller as directed by the utility.

For utilities employing a SCADA network, the SDFA-ATS can be connected to an RTU to enable remote supervision, monitoring and control of the system (Fig. 11).

![Fig. 13. Front-panel operator interface for the 7SJ80 automation controller](image-url)
Operating modes

Through various SDFA-ATS operating modes, the transfer function can be automatically or manually initiated or blocked, and enabled, disabled, or modified as operating needs and conditions change. A full-functioned, realistic simulation mode allows the system to be programmed, configured and tested without actually operating any recloser device. A live test mode facilitates field testing for verification and commissioning purposes.

System operating modes include:

- Auto source-transfer
- Normal transfer
- High-speed transfer
- Block transfer with overcurrent pickup
- Auto restoration
- Manual restoration
- Open transition
- Closed transition
- Simulation
- Live test

Auto source-transfer mode

The auto source-transfer mode enables automatic source transfers. Automatic operations are functional only when auto source-transfer mode is active, and are automatically disabled whenever there is a system communication fault, operation failure, a hot line tag is in place, or when a line fault occurs and the system is in block transfer with overcurrent pickup mode. Fig. 14 shows the selection logic for auto source-transfer mode.

![Auto source-transfer mode selection logic](image-url)
A system communication fault occurs whenever unexpected communication delays occur at an automation controller. The controllers continuously check the validity of incoming data and issue a communication fault when any unusual delays are encountered.

An Own Device Operation Failure occurs whenever a controller sends a trip or close command and the associated own recloser does not respond within a specified amount of time. An External Device Operation Failure occurs when the external recloser fails to operate properly.

The Hot Line Tag signal is carried between the recloser and controller through the recloser control cable. Whenever the signal is present, the activate command from the automation controller is inhibited, precluding automatic system operation. Similarly, when an External Device Hot Line Tag signal is issued by the other recloser via the direct fiber link, system operation is inhibited.

**Normal transfer mode**

Source transfers can be configured as being either high-speed or normal. When normal transfer mode is active, recloser device 2 operates immediately after recloser device 1 for a total elapsed transfer time of 8.4 cycles or 140 milliseconds when a type SDR recloser is used (Fig. 15). Operational logic for the normal process is shown in Fig. 16.

![Diagram](image-url)

*Fig. 15. Normal transfer mode operational sequence*

![Diagram](image-url)

*Fig. 16. Normal transfer mode operational logic*
**High-speed transfer mode**  
High-speed transfer mode is active whenever normal transfer mode is disabled. When high-speed transfer mode is active, recloser devices 1 and 2 operate near-simultaneously for a total elapsed transfer time of less than six cycles or 100 milliseconds when a type SDR recloser is used (Fig. 17). Operational logic for the high-speed process is shown in Fig. 18.

![Diagram of high-speed transfer mode](image)

*Fig. 17. High-speed transfer mode operational sequence*

**Device 1 Operational Logic**

Auto Source Transfer is ON  
Own Source is OFF  
External Source is ON  
Own CB 52-a  
\[\text{AND}\]  
OFF Command

**Device 2 Operational Logic**

Auto Source Transfer is ON  
Own Source is ON  
External Source is OFF  
Own CB 52-b  
Transfer Sequential  
\[\text{AND}\]  
ON Command

*Fig. 18. High-speed transfer mode operational logic*
Block transfer with overcurrent pickup mode

When enabled, the block transfer with overcurrent pickup mode blocks source transfers when the automation controller undervoltage and overcurrent elements pick up at the same time (Fig. 19). This condition typically occurs when a fault at or near the critical load increases the line current and collapses the feeder voltage. When such a fault occurs, the controller issues an alarm and disables auto source-transfer mode, which precludes source transfers to allow sufficient time for the feeder protection to isolate the fault.

Auto restoration mode

Once a preferred source has become available, the distribution feeder must be restored to its normal, default operational state. This can be done in three ways:

- Automatic restoration, automatically initiated
- Automatic restoration, manually initiated
- Manual restoration

Automatically initiated automatic restoration automatically reconfigures the feeder to its default condition. When auto
restoration mode is active, an automation controller continuously monitors the status of both sources and issues a restore command 60 seconds after the preferred source becomes available. This approach requires no human intervention as long as auto restoration mode is enabled. When auto restoration mode is disabled, the automatic restoration sequence must be initiated by an operator.

Automatic restoration mode logic is shown in Fig. 20. When both sources are active, AND gate 1 drives a 60-second timer. If after 60 seconds auto restoration and auto source-transfer modes are active, a two-second long restore command is issued via the action of AND gate 2 and the OR gate.

**Manual restoration mode**

Manual restoration mode is active whenever auto restoration mode is disabled. When manual restoration mode is enabled, an operator can manually restore the feeder by directly operating each recloser from its respective automation controller operator interface or via the SCADA network.

**Closed transition mode**

Once an automatic restoration command is issued, the resulting reconfiguration can be carried out using either closed transition mode or open transition mode. When closed transition mode is active, recloser device 1 closes and then recloser device 2 opens, thus creating a momentary transition overlap between S1 and S2 before S1 is connected to the critical load (Fig. 21). Closed transition mode operational logic is shown in Fig. 22.

The system is capable of performing a synchronization check following a closed transition when it is wired to sample the same phase voltage on the source and load sides of the recloser (Fig. 8 or 10) and when necessary logic and settings are implemented in the automation controller. Use of a sync-check function will increase operational delays on close commands and in the case of configuration option 2, will limit loss-of-source detection to a single phase.

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![Fig. 20. Automatic restoration mode operational logic](image1)

![Fig. 21. Closed transition mode operational sequence](image2)
Open transition mode
Open transition mode is active whenever closed transition mode is disabled. When open transition mode is active, recloser device 2 opens followed by recloser device 1, thus creating a momentary break between S1 and S2 before S1 is connected to the critical load (Fig. 24). Open transition mode operational logic is shown in Fig. 23.
Simulation mode
For test and analysis purposes, simulation mode allows the operator to simulate switching sequences without actually operating any reclosers. Once enabled, source on/off conditions can be simulated to initiate sequences. If during simulation a true loss-of-source is detected, the controller will automatically disable simulation and initiate an actual transfer sequence.

Live test
For test and commissioning purposes, live test mode provides an effective means to verify actual system performance in the field. Use of the mode eliminates the need to disconnect and reconnect wiring, and when used in conjunction with the SIGRA analysis software tool (Fig. 26), an accurate picture of system performance can be formed by analyzing the fault records stored within each automation controller.

Fault recording
Whenever any loss-of-source or restoration operations occur, either during actual or simulated operations, the automation controller stores a 1.5-second-long oscillographic fault recording of each event. For test and analysis purposes, recent event data can be downloaded using the Siemens DIGSI software tool.

To ensure accurate time stamping for system events, the clocks in the automation controllers are synchronized by Network Time Protocol data carried over the fiber optic cable linking the controllers. For systems using wireless links, an optional GPS module available with the 7SC80 controller can be used to provide synchronized time-stamping capabilities.

Once event files have been downloaded, system performance can be analyzed using Siemens SIGRA analytical software (Fig. 26) and other standard tools (Fig. 25). Both binary and analogue data is stored for the various operating modes, recloser operations and source performance.

Fig. 25. System performance test results

Fig. 26. SIGRA analysis screen
Flexible implementation

SDFA-ATS can be delivered with all required hardware and software for immediate implementation or designed to retrofit with existing equipment. The use of reclosers instead of motorized switches will result in maximum system operating speeds and preserve full feeder protection capabilities.

For utilities needing only to protect a critical load, configuration option 2 (Fig. 6) offers maximum economy, effective performance and rapid rollout. This option can be implemented within one month after receipt of order and provides customers with immediate benefit. When the system is outfitted with reclosers, outages often last less than 100 milliseconds, which means they go unnoticed by even the most demanding consumers.

Configuration option 1 offers the same benefits as option 2 and provides traditional feeder protection functionality. This option is ideal for new installations or for utilities considering replacement of obsolete or aging recloser equipment.

Configuration option 3 is intended for utilities looking to make incremental improvements to their existing distribution systems or to safeguard previous investments. Siemens engineers can work with existing equipment of any make to design a successful retrofit.

To help ensure a problem-free deployment, the automation controller and other Siemens equipment supplied with the system are completely configured and tested in the Siemens Smart Grid laboratory in Wendell, N.C., (Fig. 27). Furthermore, Siemens offers a full range of system support products and services, including on-site and factory support, testing and analysis, accessories, training, and product documentation.

Fig. 27. Recloser and circuit breaker undergoing test at the Siemens Smart Grid laboratory, Wendell, N.C., USA.

Find out more today!

To discover how SDFA-ATS can help maximize your distribution feeder availability, please contact your nearest Siemens representative. We’ll be pleased to discuss your specific needs and offer a solution that will increase customer satisfaction and reduce service costs.