Piloting Scheme Report

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General Philosophy

This report details the piloting schemes selected to protect the four transmission lines connected to the Ames Substation. Each piloting scheme was selected to maximize reliability through primary and secondary schemes. Additionally, each transmission line shall receive and transmit Direct Transfer Trip (DTT). The DTT protocol shall act due to a local breaker failure, bus fault, or transformer failure that the primary and secondary pilot schemes did not clear. DTT will key a signal to either re-trip the local breaker, or to trip the remote breaker and communicate a lockout of the fault. DTT responds to both single-phase and three-phase faults, ensuring the protection of electrical equipment connected to Ames Substation.

Three major characteristics of each line were considered when selecting the piloting schemes. The first is the availability of fiber optic ground cables to use as a communication channel. A transmission line with fiber cable can be protected using differential and permissive piloting schemes like 87L and Permissive Overreaching Transfer Trip (POTT). Lines without fiber cable shall utilize the power line as the communication channel. The length of the transmission line contributes to the piloting scheme selection because a longer line experiences more unbalanced currents, so that a differential protection scheme becomes less practical. Another consideration is that the solar farm terminal is an inverter-based power source. Automatic reclosing of this line is not reliable when the power source can become out of phase after a fault.

Transmission Line Protection

Ames-Ankeny Transmission Line with Huxley Connection (23 mi):

- Voltage 138kV
- Primary Pilot Scheme: Directional Comparison Blocking (DCB)
- Secondary: Directional Comparison Unblocking (DCUB)
- Communication: Power Line Carrier (PLC)
- Auto-reclosing

The Ames-Ankeny line only has PLC available for communication and shall utilize a DCB scheme for primary protection. Other piloting schemes like POTT require a constant communication channel to operate. POTT is not compatible with PLC communication because a fault in the line would interrupt the communication channel. DCB can be used here as it operates with an on/off blocking signal. This allows the DCB scheme to trip if the signal is lost.

DCUB shall be used for the secondary piloting scheme. DCUB also communicates on the PLC but utilizes frequency-shift keying (FSK) for coordination like a POTT scheme would. FSK communication increases the variability of the coordination in this line. DCUB acts like POTT where the logic waits for permission to trip; however, in the event of a fault and PLC communication is lost, the DCUB logic allows it to trip without receiving the tripping frequency.

DCB and DCUB prevent tripping the substation breaker if the relay sees the fault outside the transmission line between Ames and Ankeny. This shall provide extra reliability for the Huxley connection. This line does not connect directly to a power source such as a synchronous generator so the relay's auto-reclosing functions shall be used. The auto-reclosing function can reclose the breakers if the fault is cleared quickly, such as lightning hitting the line or a tree branch brushing against it.

Ames-Boone Transmission Line (15 mi, 138kV)

- Primary Pilot Scheme: 87L
- Backup: POTT
- Communication: Optical Ground Wire
- Auto-reclosing

The 87L current differential shall be used as the primary for this line as it has an optical ground wire for communication. This means 87L can be used to protect this line by measuring the currents on both ends to ensure the current is nearly equal. For the POTT scheme, a function is used to check if the trip signal is sent from both the local and remote relay to determine the output for the trip function. The function requires a constant channel of communication to operate provided through an optical ground wire. Using the POTT and 87L on this line will provide extra variability and resilience by providing protection using distance relays with the POTT scheme and the 87L current differential. This line shall use the relay’s auto-reclosing function.

Ames-Nevada Transmission Line (2.5 mi, 138kV)

- Primary Pilot Scheme: 87L
- Backup: 87L
- Communication: Optical Ground Wire
- Auto-reclosing

The Ames Nevada line is relatively short and has optical ground wire available for communication. Optical Ground wire provides a reliable communication channel so the 87L can be used. The distance relays require sufficiently long lines for the impedance measurements to function properly as this line is short POTT does not make sense to use for backup or primary piloting. The line shall use the relay's auto-reclosing functions.

Ames Solar Farm (0.5 mi, 69kV)

- Primary Pilot Scheme: 87L
- Backup: 87L
- Communication: Optical Ground Wire

- No Auto-reclosing

The Ames to solar farm line is relatively short and has optical ground wire available for communication. Optical Ground wire provides a reliable communication channel so the 87L can be used. The distance relays require sufficiently long lines for the impedance measurements to function properly as this line is short POTT does not make sense to use for backup or primary piloting. The line shall not use the Auto-reclosing function of the relays because of the possibility of the source and transmission line voltage and current moving out of phase during the fault. This could happen because the line is connected to a power source where the phase angle of the current and voltage is driven by the source.