

# Case Study of a Multiterminal Generation Interconnect Scheme

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**Abstract**— Imperial Irrigation District (IID) Energy provides electric power to more than 140,000 customers in the Imperial Valley and parts of Riverside and San Diego counties. As the sixth largest utility in California, IID Energy controls more than 1,100 MW of energy from a diverse resource portfolio that includes its own generation and long-term and short-term power purchases.

IID Energy's customer Ormat Technologies, Inc. installed an additional 30 MW of geothermal generation at Heber South in the Imperial Valley. This new facility connects to the 92 kV IID Energy grid at El Centro, California. Heber Imperial and Second Imperial Geothermal Company, two nearby existing Ormat geothermal generating facilities, also supply 60 MW to the IID Energy grid.

The three generating facilities are within a half mile of each other but are connected to the IID Energy grid via separate GSU (generator step-up) transformers. IID Energy can connect these Ormat generating facilities to the Highline Substation via a dedicated transmission line or as a tap on the El Centro-Pruett transmission line. This paper discusses the implementation of a multiterminal protection and system integrity protection scheme (SIPS) at IID Energy, the design challenges of this implementation, and proposed improvements to the existing protection scheme.

## I. INTRODUCTION

### A. Imperial Irrigation District (IID) Energy Background

IID Energy provides electric power to more than 140,000 customers in the Imperial Valley and parts of Riverside and San Diego counties, as Fig. 1 shows. As the sixth largest utility in California, IID Energy controls more than 1,100 MW of energy from a diverse resource portfolio that includes its own generation and long-term and short-term power purchases.



Fig. 1. IID Energy serves more than 140,000 in Southern California

### B. IID History

The opportunity for IID to enter the power business arose after the 1928 passage of the Boulder Canyon Project Act. Part of this act required that the Secretary of the Interior obtain local guarantees of repayment for the construction costs of the All-American Canal. IID recognized that the people of the Imperial Valley could repay their share of the construction loans if they were given the right to use the canal to produce power. The Secretary of the Interior and the IID signed such an agreement in 1932, and construction of the All-American Canal began in 1934. Just two years later, IID entered the electrical power business, harnessing the hydroelectric power generated from water that flows through the canal.

### C. IID Energy Presently

Presently, IID Energy is a nonprofit public power utility governed by a locally elected, five-member board of directors. The utility employs more than 1,000 and had energy sales revenues of more than \$400 million in 2007.

IID Energy produces some power locally, using efficient, low-cost hydroelectric facilities, steam generation facilities, and several natural gas turbines. The utility also owns portions of nuclear and coal generating facilities outside California. To help meet its summer peak demand, IID Energy acquires additional energy resources from purchased power contracts and capitalizes on opportunities in the open market.

One of five balancing authorities in California, IID Energy owns and operates more than 1,300 miles of high-voltage transmission lines that span the utility's 6,471-square-mile service territory. IID Energy is a leader in the transportation of clean and renewable energy; its transmission system interconnects with key load-serving organizations within the Western Grid.

## II. CURRENT PROJECT

### A. Description of the System

As Fig. 2 illustrates, the system consists of three discrete generating facilities that can be connected to one of two 92 kV transmission lines. One line is a dedicated line for the generating facility, while the other is a tap onto a two-terminal line creating a multitap line. The lack of a switchyard for the generators at the facility adds to the complexity of the system. Being able to use remote-controlled motor-operated switches to switch between the dedicated line and the tapped line increases operating flexibility, but it also adds complexity to the protection requirements. The project includes the following substations:

- Ormat Substation – Ormat is a geothermal facility that consists of the following three generating units: Heber South (HS), Heber Imperial (HI), and Second Imperial Generation Company (SIGC). These generators are within a half mile of each other, and each unit is connected to the IID Energy grid at 92 kV via separate captive GSU transformers.
- El Centro Switching Station (ECSS) – This substation uses a single 92/230 kV autotransformer bank to interconnect the IID Energy system to Southern California Edison (SCE) at 230 kV.
- Prueett Substation (PW) – This substation is a weak terminal with a single-source transmission line connecting it to the IID Energy transmission system.
- Highline Substation (HL) – This substation, which provides a path for transferring power from IID Energy to SCE, is connected to the IID Energy Midway substation via two 230 kV lines. Two 92 kV lines, one from Ormat and one from E. Mesa, connect to this substation.

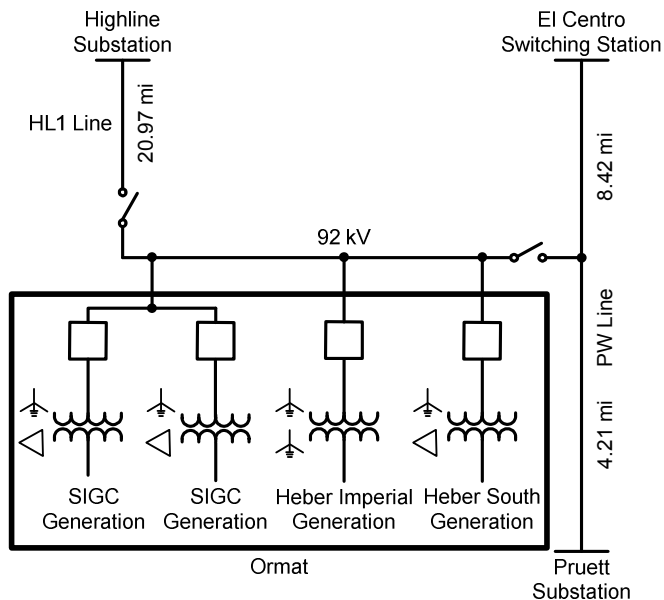


Fig. 2. Lack of a switchyard adds complexity to the system

### B. Existing System Protection

- Ormat Substation – Heber South is the new unit Ormat is installing as part of the system upgrade. Redundant microprocessor relays provide protection. Included in this design is a logic processor necessary for the new control system. The protection for Heber Imperial is a microprocessor relay that has all of the features that the new scheme needs. The primary protection for SIGC is a vintage microprocessor relay and a secondary electromechanical relay system, which lack the protection features that the new scheme must have. The Heber Imperial generation site is a limited source for ground faults on the IID Energy system. To detect such faults, this site must have negative-sequence overcurrent and zero-sequence overvoltage protection.

- El Centro Switching Station – Redundant vintage microprocessor relays provide protection for the line. Neither of the two relays, each from a different relay manufacturer, has the protection features or the logic flexibility of a modern microprocessor relay.
- Prueett Substation – The line protection at this station is similar to that at the El Centro Switching Station. Additionally, this station is a weak infeed terminal for a single-source contingency.
- Highline Substation – The line protection at this station, a vintage microprocessor relay backed up by an electromechanical relay system, is similar to that for SIGC.

### C. Protection and Expansion

To reduce project costs, IID Energy chose to restrict new relay purchases to the Ormat facility and to only upgrade the communications system between the Ormat Substation facility and the three outlying substations.

- Ormat Substation – An evaluation of the equipment at Ormat revealed that the microprocessor relay used on the existing Heber Imperial unit was sufficient for the new application. Although it is best to have redundant protection, the upgrade excluded a second relay. The SIGC unit needed replacement of the vintage microprocessor relay with a new microprocessor relay to communicate with the logic processor IID Energy installed as part of the upgrade. IID Energy left the electromechanical relay system in service as a step distance backup system. With the addition of this new generation at Heber South substation, this plant will be working as a three-terminal generating station. This is because the three units do not tie to a switching station; they instead connect independently to the transmission line. The microprocessor relays from the three Ormat generating facilities are connected to the logic processor. The logic processor effectively combines the trip, permissive, and breaker failure logic of the three substations into one common terminal. With the three terminals now configured as a pseudo single-line terminal, system designers developed permissive overreaching transfer trip (POTT) with weak infeed [1] [2], Zone 1 (Z1) step distance, direct transfer trip (DTT), and a breaker failure (BF) scheme within the logic processor.
- El Centro Switching Station – IID Energy wanted to upgrade the primary and secondary relay protection to match the operating principles of the relays at Ormat. IID Energy wanted this upgrade because correct operation of directional elements is critical for the POTT scheme in multiterminal line applications. Although IID Energy did not replace the relays, IID Energy personnel selected settings and logic that use DTT, POTT, step distance including Zone 1, and backup overcurrent protection to protect the multiterminal lines. Because these vintage relays on the IID Energy system have high failure rates, IID Energy plans to replace at least one of the existing

relays with a relay that has operating principles similar to the relays at Ormat.

- Pruet Substation – The upgrades at this station are similar to those at the El Centro Switching Station.
- Highline Substation – The upgrades at this station are also similar to those at the El Centro Switching Station. In addition, IID Energy installed an SIPS relay at this location. The system uses this relay to detect a loss of transformer load. The SIPS activates for a change from a load condition to a no-load condition. The scheme monitors the breaker positions (open phase detection) for those breakers connected to the transformer. The relay uses an overcurrent element to supervise declaration of no load for cases where the breaker is opened inadvertently. When the SIPS relay detects no load, the scheme communicates this status to Ormat, causing Ormat to reduce generation to the IID Energy grid.

One requirement of the new system is that it must switch the generation at Ormat between the Highline substation and the ECSS and Pruet tap line. Two settings groups are necessary for coordinating the system properly for the two operating conditions at Ormat. When the generation is connected to Highline, the relays will switch automatically to Setting Group 1. When generation is connected to the ECSS and Pruet tap line, the relays will switch to Setting Group 2. The position of the line tap switch on the ECSS and Pruet line determines this automatic settings group selection. Protection is more challenging when the Ormat generation is connected to the ECSS and Pruet tap line. For this condition, the system bases the decision to switch to Group 2 solely upon when the line tap switch ties the generation to the tap line. The system transmits information about the position of the switch via radio to the logic processor. The processor then controls which group to make active. Because this is a radio link between the switch and the logic processor, the system includes a manual bypass switch for cases where the signal might be lost. In a similar manner, the system monitors the position of the line switch on the Highline HL1 line. When the switch is open, the system sends a constant POTT key permissive signal to the relays at Heber South to enable high-speed tripping for all faults.

#### D. Protection Complications

The relays at the three remote substations were originally configured as a step distance scheme. Because of the new generation at Ormat, IID Energy added POTT to the new scheme. IID Energy installed new digital communications equipment at each site for the POTT communications path. There is a dedicated path between the El Centro Switching Station and Pruet. There are also paths that connect El Centro Switching Station, Pruet, and Highline substations to Ormat. Between El Centro Switching Station, Pruet, and Ormat, the communications paths transmit only POTT signals. From Highline to Ormat, the paths also transmit load/no-load status.

The existing relays at the three remote stations are configured as a POTT scheme. Relays of this vintage lack the features of the relays at Ormat. One missing feature is the ability to echo key or key for a weak system condition. IID

Energy has slated at least one relay system at each remote site for a replacement that will add these features. IID Energy will then reevaluate the system. For this project, IID Energy selected settings to enable each terminal to see the faults, with some possibility that a terminal could trip sequentially on weak terminal faults. IID Energy evaluated this possibility and determined it to be an acceptable risk.

For the system to select the proper group automatically, the logic processor must have information about the status of the line disconnect switches associated with the Ormat facility. For system security, the system sends the status of both the motor-operated disconnect 89a switch and the motor-operated disconnect 89b switch to the logic processor. The logic processor checks the status of the two switches to ensure that there is no disagreement between each 89a switch and 89b switch. If the 89a switch and 89b switch are both open or both closed, the logic processor will send an alarm to the SCADA system. In addition, the logic processor will assert a discrepancy alarm if both the Highline tap switch and the ECSS /Pruett tap switches are closed. To allow time for the switch to operate, the logic includes a one-second delay. Fig. 3 shows a sample of the logic for the Highline switch (HL1B1). The logic depicts use of discrete AND and OR gates to obtain exclusive OR gate functionality.

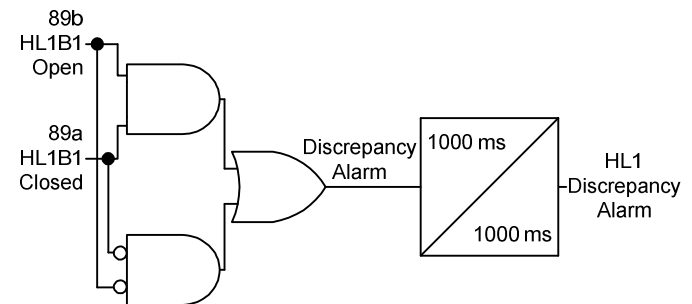


Fig. 3. HL1 and PW Line switch discrepancy alarm logic

Fig. 4 shows the settings group logic for Setting Group 1. This logic operates as follows: When the Highline tap switch is closed, the ECSS/Pruett tap switch is open, the discrepancy alarm is not asserted, and the system is in automatic operation, the logic sets a software latch. A manual override switch is in place for when Group 1 blocks automatic operation, and this switch forces the logic to select Group 1. A timer prior to group selection provides the system time to stabilize before it changes settings groups. Once the logic enables Setting Group 1, the Setting Group 2 latch resets. This circuit is similar to the Setting Group 1 latch reset.

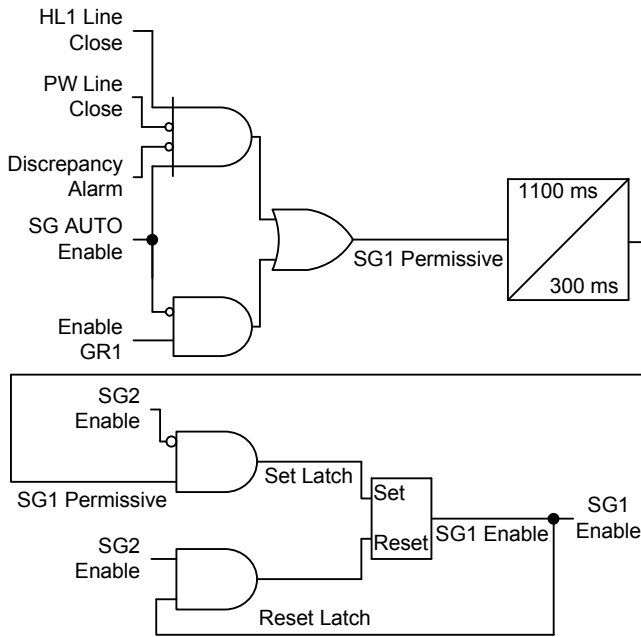


Fig. 4. Logic forces selection of Setting Group 1

Zone 1 tripping for the three generating units also requires special logic, shown in Fig. 5, in which Zone 1 is set for each relay. The other two units are so close that it was necessary to develop logic to prevent the Zone 1 element of one relay from seeing transformer faults for an adjacent unit. To block the relay from responding to faults from adjacent units, each relay sends a block signal from a reverse-looking Zone 3 (Z3) element. The Z3 Reverse Block Logic is simply the ORing of the Z3 elements from all the Ormat substations into the logic processor. This Zone 3 element is also part of the POTT scheme we discuss in the following text. It was necessary to add a one-cycle delay to each Zone 1 trip to allow time for the Zone 3 blocking element to assert and signal the logic that the fault is behind one of the relays. Three of the four relays at Ormat had a delay timer associated with Zone 1, but the one early vintage relay did not have this feature. For this relay, IID Energy added a delay timer to the logic processor. The other relays use their internal timers to delay Zone 1. This signal trips the three units at Ormat. If the Z1/DTT trip toggle switch is on at Ormat, then this signal will be sent to the remote terminals. No difference exists between a Zone 1 trip and a breaker failure trip at the remote terminals, so IID Energy added this Z1/DTT trip toggle switch to the scheme. The switch is necessary because this trip operates a lockout relay that must be manually reset at the remote terminal.

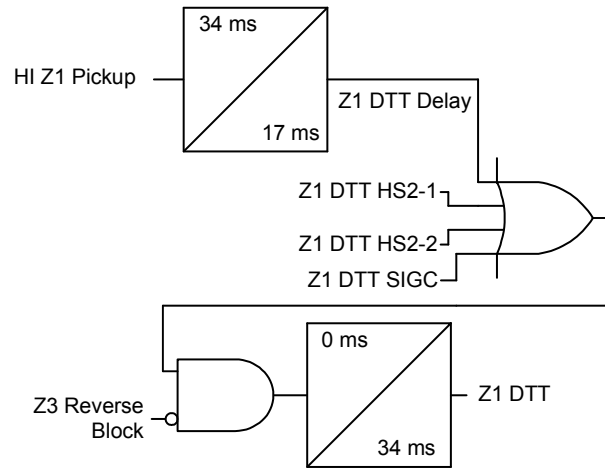


Fig. 5. Zone 1 tripping needs special logic

Permissive overreaching transfer trip is similar to the Zone 1 tripping we discussed previously. Fig. 6 shows this POTT logic. Each relay at Ormat site sends a Zone 3 reverse block signal and a key permissive signal to the logic processor. This logic uses a two-cycle delay to coordinate the Zone 3 elements with the Zone 2 trip elements. The timer has a five-cycle dropout to maintain the key permissive signal to the remote terminals. Once a key permissive signal asserts, the logic ANDs the logic output with the settings group select status. The logic then routes the key permissive signal either to ECSS and Pruett substations if Setting Group 1 is selected or to Highline substation if Setting Group 2 is selected. The Permissive signal is constantly keyed for the Highline terminal if Setting Group 2 is selected. Therefore, if Ormat is tied to the Highline substation, then the logic processor transmits a constant key signal to both ECSS and Pruett substations, as the logic in Fig. 7 shows. This arms the POTT signal, allowing a high-speed trip when Ormat is not connected to PW line. In the case of ECSS and Pruett, the permissive signal must be present from all the remote stations. The system ANDs these permissive signals into a single input. This AND logic is necessary because the relays at both ECSS and Pruett cannot be configured for other than a two-terminal line.

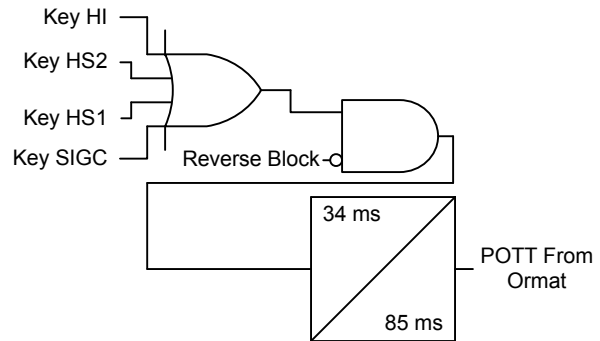


Fig. 6. Key permissive logic is similar to Zone 1 trip logic

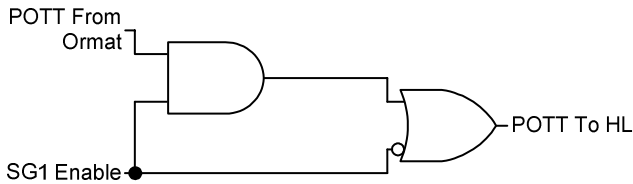


Fig. 7. Logic transmits permissive signal to Highline

As stated previously, the Zone 1 direct transfer trip and breaker failure trip to the remote terminal use the same channel. Fig. 8 shows the logic for a Highline remote trip. First, the settings group selection must indicate that Ormat is associated with the line. In this case, such indication is from the fact that Setting Group 1 is active. If the logic receives a breaker failure signal from any of the local protective relays, it declares a breaker failure and sends a trip signal to the remote terminal. IID Energy adds a 10-cycle dropout to the signal because it operates a lockout relay at the remote terminal. The Zone 1 direct transfer trip enable must be asserted for Zone 1 to route the DTT signal to the remote terminal. IID Energy requires this enable, a simple toggle switch, for maintenance personnel. The logic transmits information about the status of this switch to the logic processor.

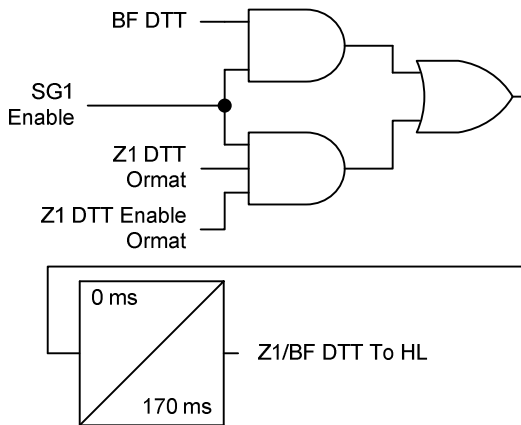


Fig. 8. Breaker failure logic produces a remote trip

Fig. 9 shows the breaker failure logic that the three terminals use to trip the local breakers. Group selection determines which remote signal, and which locally generated breaker failure trip signal, route to the local relays. Similarly to the Zone 1 and breaker failure signal combination for the remote stations, these signals combine into a single trip signal from each remote site. Local breaker failure information originates with each relay containing breaker failure logic; only the trip output routes through the logic processor.

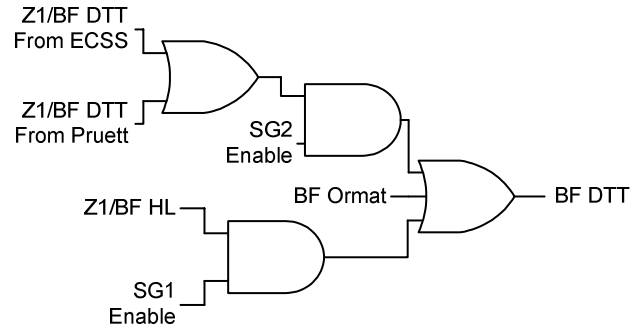


Fig. 9. The terminals use breaker failure logic to trip local breakers

*E. SIPS Logic*

When Ormat generation is connected to Highline, the IID Energy system will become unstable if the 230/92 kV transformer at the Highline substation is out of service. The SIPS monitors breaker positions and load flow to initiate a trip if the IID Energy is lost. Fig. 10 shows the SIPS system for Highline. This system checks for at least one closed breaker on each side of the transformer and for a minimum current through the transformer. The load detector prevents misoperations if a breaker is physically closed, but status information for that breaker is unavailable. The scheme provides additional security by sending information about load and no-load conditions to Ormat.

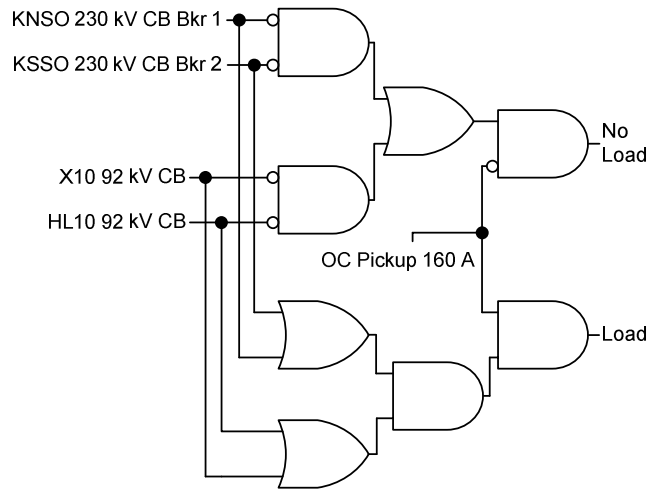


Fig. 10. SIPS logic at Highline checks for a closed breaker and for minimum current

Fig. 11 shows the SIPS logic for Ormat. Once Ormat receives the SIPS signal, it must declare that load is present for at least one second before it can arm a trip. To further secure the logic, the system must transition from a load to a no-load condition within 10 cycles (approximately 168 ms). Otherwise, the system will block on the premise that the logic lost the signal and did not initiate an SIPS trip. Group selection supervises the SIPS signal similarly to how it supervises other signals in the system. The SIPS signal only initiates an SIPS trip if the Highline line switch is closed. SIPS trip will reduce the Ormat generation connected to the IID Energy grid.

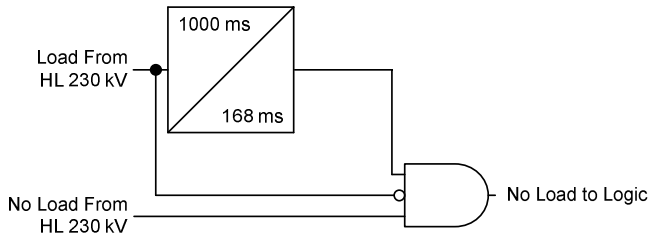


Fig. 11. A timer supervises SIPS tripping logic at Ormat

The logic processor can transmit system condition information and alarms to the control center via a DNP link. Most alarm conditions are momentary, so a five-second dropout delay for each alarm ensures that the control center receives the data. It is a simple process to program these delays by using existing timers unnecessary for protection logic. Many alarms are devoted to the various trip conditions and to transmission of POTT signals. Many alarms are not traditional alarms for which dispatcher intervention is necessary. Instead, these alarms provide instant data to relay technicians responsible for correct system operation. Fig. 12 shows a typical alarm timer. Typical alarms are for SIPS trip, Zone 1/breaker failure messages that remote stations send and receive, relay-to-relay communications channel status, line switch discrepancy, POTT key permissive and key received signals, and Zone 3 reverse block. The logic processor provides easy access to the various alarm conditions without any need for special wiring to bring a contact to the remote terminal unit (RTU).

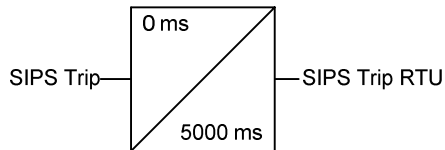


Fig. 12. Alarm timers provide data to technicians

#### F. On-Site Testing and Commissioning

It can take as long as two days and cost as much as \$100,000 per day in revenue losses to normalize geothermal generators and place units back in service. The commissioning of this project was challenging, because the system was in service. It was critical that logic be verified [3] completely and without tripping any units. Because of the protection scheme complexity, it was necessary to verify the complete logic before implementing the entire scheme. As part of verifying logic processor operation, test engineers had to ensure that the logic processor sent information to the correct relay or relays for further action. The Ormat substation logic processor, for example, collects information from all local relays and communicates with remote end relays.

As part of commissioning, test engineers verified settings group change (based upon whether the switch position was for the HL1 or the PW Line) and the SIPS, POTT, and Z1/BF DTT logic. During commissioning, test engineers blocked communications-assisted tripping, and only the step distance scheme was in service. In the case of the POTT scheme, for example, it was necessary to initiate POTT from one relay at a time and to verify the operation of Zone 3 reverse block from

other relays one at a time. After detailed logic verification and confirmation that all information exchange occurred properly between relays and the logic processor, test engineers monitored the system for any standing trip. For this project, commissioning was successful without any false trips or outages to a running geothermal unit. The scheme has been in service since.

#### G. Summary

There are budget and time requirement considerations with any design, and this project is no different. IID Energy identified some areas for improvement, but overall the system design meets requirements for the application. Future work will, at a minimum, upgrade relay protection at the remote sites. When these upgrades occur, IID Energy will also upgrade the communications channels so that remote relays can communicate directly to the logic processor. Once these upgrades are in place, it will be possible to separate such functions as breaker failure and Zone 1 direct transfer trip into different signals. Until the upgrades occur, the system will have adequate protection. With the Ormat facility connected to ECSS and the Pruett tap, the Highline substation successfully cleared a fault via POTT because the logic processor was transmitting the key permissive signal. This fault did not challenge the total complexity of the system, but it did demonstrate the system's viability.

#### H. On-Site Operation Details

The SIPS has not needed to operate since it was installed. However, an April, 13, 2009 test demonstrated correct operation of the project protection scheme. POTT key logic is enabled according to the switch status at Ormat, as Fig. 2 illustrates. Therefore, if the line switch is open for the line from Ormat to Highline, the Ormat end always sends a permissive signal to Highline. During the 2009 test, POTT operated correctly on the HL1 line for the transient fault, even though Ormat was connected to the PW line. When the Highline-Ormat line is energized from the Highline end, and the switch for the Highline line is open at the Ormat end, the POTT scheme is in service.

### III. FUTURE WORK

This section discusses future improvements for this project and the SIPS at Highline. It also compares the proposed scheme to the installed scheme.

#### A. Future Proposed System

Fig. 13 shows the simplified proposed future protection scheme. This scheme will require that IID Energy perform the following:

- Upgrade the relays at ECSS, Pruett, and Highline substations.
- Install new relay-to-relay communication between, Ormat-ECSS/Pruett and Ormat-Highline.
- Upgrade the SIPS at Highline. The SIPS at Highline will use the upgraded relays at Highline and synchrophasor technology. (The following text discusses details of the future SIPS and the SIPS upgrade at Highline).

- Install satellite-synchronized clocks at Highline, Ormat, ECSS, Pruett, and Midway to provide synchronized satellite signals. These clocks will also provide highly accurate signals necessary for synchrophasor measurement.
- As an option, install a dual redundant protection scheme with primary and backup relay [4].

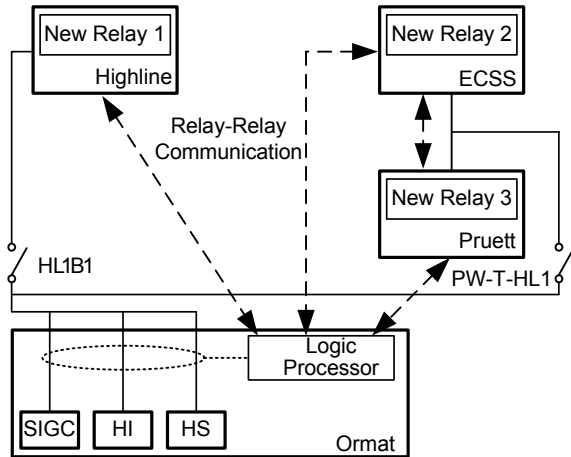


Fig. 13. Proposed future system has a number of improvements

In addition to the future proposed scheme, an optional scheme would include an additional logic processor and an additional microprocessor relay at each substation. This will comply with the redundancy requirement of the SIPS. A primary relay at each substation would connect to a primary logic processor, and a backup relay at each substation would communicate with a backup logic processor.

### B. Improvements

This section discusses the improvements of the future protection scheme over the existing scheme. It also documents details of the future SIPS and advantages of this scheme over the existing scheme.

#### 1) Relay Upgrade:

The proposed protection scheme would include installation of new microprocessor relays to overcome the limitations of existing relays at ECSS, Pruett, and Highline. For the multiterminal lines, it is recommended to select relays with the same operating principles as for directional elements. For the POTT scheme, correct operation of directional elements is critical. Existing relays at the remote stations for Ormat are vintage microprocessor relays. New microprocessor relays are better equipped to handle this complex protection scheme. In addition, the existing relays and protection scheme do not have weak infeed logic for multiple terminals. (Ormat and Pruett must each use weak infeed logic).

Through use of the proposed relay upgrades, it will be possible to enable weak infeed logic at multiple terminals and to enable multiple settings groups for different system configurations. In addition, selecting new digital relays with identical operating principles can minimize error resulting from misoperation of directional elements. Time synchronization of the relays is beneficial for the analysis of complex systems. The future scheme will also use

synchrophasor technology and the advantages of future SIPS improvements to improve the SIPS at Highline.

#### 2) Communications:

The proposed protection scheme also calls for improved relay-to-relay communication between Ormat-ECSS/Pruett and Ormat-Highline. Through the use of relay-to-relay communication (MIRRORED BITS<sup>®</sup> communications), it will be possible to transfer additional digital bits, which otherwise would have required hardwired contacts to exchange information between Ormat and remote substations of interest. Relay-to-relay communication will occur through a self-monitored communications channel. When relay-to-relay communication is installed, each communications channel will be able to transfer and receive eight digital bits. (The existing scheme uses one IMUX hardwired contact for each bit of digital information transferred).

By using this relay-to-relay communication, it will be possible to use additional communications bits to also enable weak infeed logic for multiple terminals. The proposed scheme will also use separate digital bits for Z1DTT, and BF. In the existing protection scheme, Z1DTT, and BF for the remote stations from ORMAT transfer as single digital bits; remote substations cannot distinguish between Z1, DTT, and BF trip. For the additional spare bits, it will be possible to transfer to Ormat digital information regarding breaker status to determine transformer/line outage/in service. System information can be obtained via the SCADA at Ormat.

#### 3) Synchrophasors:

A decade ago, synchrophasors were available only in standalone phasor measurement units (PMUs). Today, many digital relays have synchrophasor measurements [5] [6], and IEEE standard C37.118 [7] is widely accepted as the preferred method for exchanging synchrophasor measurements. Digital relays provide time-aligned synchrophasor messages with communication rates as fast as 60 messages per second. The proposed protection scheme would use relay-to-relay synchrophasor communication to calculate the phase angle difference for SIPS protection. Fig. 14 shows an example of the proposed logic. Area 1 shows the IID Energy Midway substation, while Area 2 and Area 3 indicate the Highline and Ormat substations, respectively, of IID Energy. The SIPS will measure the phase angle difference between Midway and Highline stations, trigger SIPS based on predefined angle difference thresholds, and send a generation-shedding command to Ormat. [8]

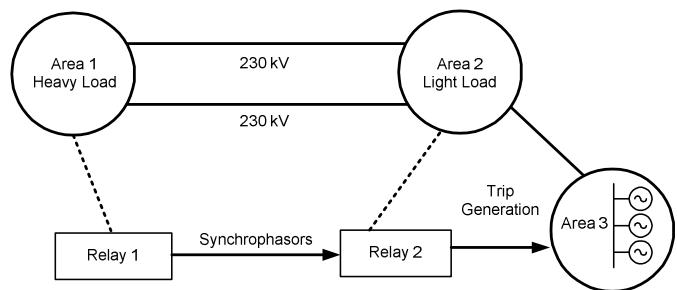


Fig. 14. Logic would use synchrophasors for communication

#### 4) SIPS Upgrade at Highline

Fig. 15 shows the future SIPS at Highline. Under the proposed scheme, IID Energy will install a synchrophasor-capable relay at Highline, and this relay will exchange information to the existing synchrophasor-capable relay at Midway. The proposed SIPS at Highline will use phase angle information that these two relays (Highline and Midway) exchange, and SIPS protection trip will be enabled in case

power flow goes below the minimum threshold. The existing SIPS monitors breaker contact. The future scheme will not require breaker contacts at Highline; the scheme can use synchrophasors and power flow measurement to establish correct SIPS tripping. This scheme will be part of an SIPS in a future Western Electric Coordinating Council (WECC) Path 42 SIPS.

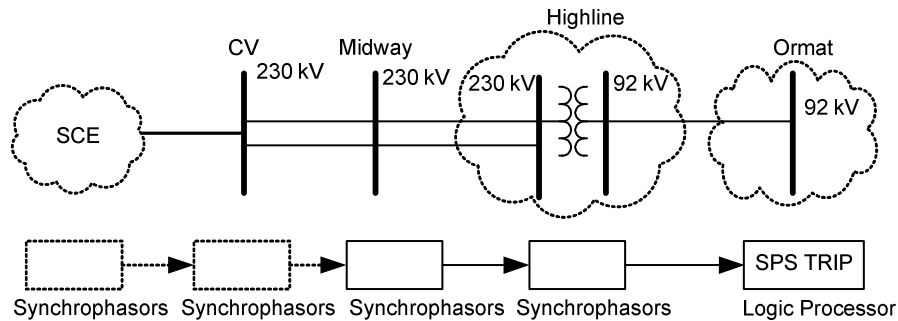


Fig. 15. Future SIPS at Highline includes a number of upgrades

The WECC Path 42 consists of a double-circuit 230 kV line that belongs in separate parts to IID Energy and SCE. The IID Energy portion of Path 42, approximately 20 miles, begins at Coachella Valley substation (CV) and terminates at SCE's Mirage substation. The SCE portion of Path 42, approximately 15 miles, begins at Mirage substation and ends at Devers substation. The normal load flow on these lines is from IID Energy to SCE. These lines connect to more than 400 MW of generation at Midway substation and to approximately 90 MW from geothermal generation at Ormat. By using the synchrophasor application, it becomes possible to control the amount of generation connected to the IID Energy system, according to the power export to SCE. In case of system disturbances in the SCE system, it is possible to take corresponding corrective action. This scheme can use synchrophasor technology in and around this network to also alleviate transformer overloading at Midway and any other protection-related issues.

#### 5) Advantages:

The existing SIPS protection scheme uses load current and breaker status to determine load and no-load conditions at Highline. At Ormat, the scheme transfers this information to the relay processor. Subsequently, load/no-load in the logic processor generates the SIPS trip according to programmed logic. With the future SIPS logic, the SIPS relay at Highline will determine a trip according to load flow and synchrophasor information in the SIPS relay at Highline. For the future scheme, breaker status monitoring is not necessary. Processing time in the relays and logic processor is therefore reduced. Operation time for the SIPS should decrease from 15 cycles to about 10 cycles (this includes the five cycles for breaker operating time at Ormat) [9]. In addition, because the existing SIPS requires Highline breakers to operate for any system disturbance beyond Midway, SIPS at Highline will not operate. As a result of IID Energy using the future SIPS

protection scheme, it will be possible for SIPS to operate correctly, even for system disturbances beyond Midway.

#### IV. CONCLUSION

Multiterminal distance protection schemes are complex, with multiple possible system configurations and infeeds that make it difficult to use distance relays for their protection. A recently installed protection scheme is working satisfactorily and can operate correctly for this multiterminal generation protection at Ormat. In addition, the SIPS at Ormat has programming through which it can island the Ormat generation from the IID Energy system to prevent IID Energy system instability.

By using a future proposed scheme, it will be possible to improve the protection scheme further. With new relays, it will be possible to enable multiple settings groups, reliably detect faults, and enable weak infeed logic at multiple terminals. The new relays will also improve SIPS logic and reduce SIPS protection scheme operating time. Phase angle protection will be enabled in addition to load flow calculations, and these features will reduce existing SIPS operating time by as much as six cycles. SIPS upgrades at Highline can use synchrophasor technology in a future SIPS for Path 42.

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## VII. BIOGRAPHIES

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