The 500 kv system upset at the PVNGS switchyard originated with a fault across a degraded insulator on the 230 KV Liberty line from the Westwing substation. Protective relaying detected the fault and isolated the line from the Liberty substation. The protective relaying scheme at the Westwing substation received a transfer trip signal from Liberty actuating the AR relay in the tripping scheme for circuit breakers 1022 and 1126. The AR relay had four output contacts, all of which were actuated by a single lever arm. The tripping schematic showed that contacts 1-10 and 2-3 should have energized redundant trip coils in PCB 1022, while contacts 4-5 and 6-7 should have energized redundant trip coils in PCB 1026.

PCB 1126 tripped, demonstrating that the AR relay coil picked up, and least one of the AR relay contacts, 1-10 or 2-3, closed. PCB 1022 did not trip. Bench testing by APS showed that, even with normal voltage applied to the coil, neither of the tripping contacts for PCB 1022 closed. The breaker failure scheme for PCB 1022 featured a design where the tripping contacts for the respective redundant trip coils also energized redundant breaker failure relays. Since the tripping contacts for PCB 1022 apparently did not close, the breaker failure scheme for PCB 1022 also was not activated, resulting in a persistent uncleared fault on the 230 kV Liberty line.

Various transmission system events recorders show that during approximately the first 12 seconds after fault inception, several transmission lines on the interconnected 69 kv, 230 kv, 345, and 525 kv systems tripped on overcurrent, including lines connected to the Westwing, Hassayampa substations. Also during the first 12 seconds, two Red Hawk combustion turbines and one Red Hawk steam turbine power plants tripped, and the fault alternated between a single line to ground fault to a two line to ground fault, apparently as a result of a failed shield wire falling on the faulted line. After 12 seconds, the fault became a three phase to ground fault, and additional 525 kv lines tripped.

At approximately 17 seconds after fault inception, the three tie lines between the PVNGS switchyard and the Hassayampa substation tripped simultaneously due to action of their negative sequence relaying, thereby isolating the fault from the several co-generation plants connected to the Hassayampa substation. Approximately 24 seconds after fault inception the last two 525 kv lines connected to the PVNGS switchyard tripped, isolation the switchyard from the transmission system. At approximately 28 seconds after fault inception, the three PVNGS generators were isolated from the switchyard, and by approximately 38 seconds all remaining lines feeding the fault had tripped and the fault was isolated.

Reliability Issues

The degraded insulator was caused by external contamination and did not represent a concern relative to the reliability of the insulation of the 230 kv transmission system. The failed AR relay and the lack of a robust tripping

H/2

scheme raised concerns relative to the maintenance, testing, and design of 230 kv system protective relaying. Interviews with APS T&D personnel indicated that the Westwing substation where the relay failure occurred was subject to annual maintenance and testing. Following the event, the failed AR relay was removed from service by APS and visually inspected by the NRC team at PVNGS. The relay showed no apparent signs of contamination or deterioration. Although the team considered the maintenance interval to be reasonable, the team did not determine the degree of rigor applied in testing the relaying scheme. For instance, it is doubtful that the testing included methods common in the nuclear industry such as verifying that each contact in the tripping scheme functioned properly. As noted earlier, the tripping scheme lacked redundancy that may have prevented the failure of the protective scheme to clear the fault. APS reviewed the design of the Westwing substation as well as all other substations connected to the PVNGS switchyard, and found that only the Liberty and Deer Valley lines at the Westwing substation featured a tripping scheme with only one AR relay. All of the newer lines featured two AR relays.

[EX4

In order to improve reliability, APS modified the tripping schemes for the Liberty and Deer Valley lines to feature two AR relays enegizing separate trip coils.

[EX4

Independence of Offsite Power Supplies

GDC 17 requires that power from the offsite transmission network be supplied by "two physically independent circuits (not necessarily on separate rights of way) designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions". [

EX4

The uncleared fault resulted in tripping of transmission lines both locally, and at remote substations. Lines at several interconnected transmission voltage levels tripped, commencing a few cycles after fault inception, and continuing for another 38 seconds. Even remote lines were tripped by inverse time overcurrent relays, which were not intended to

protect against remote faults, but nevertheless succumbed to the fault because its duration.

EX4

Another concern was raised by the simultaneous tripping of the three Hassyampa tie lines. The three Hassayampa tie lines featured negative sequence relaying intended to serve as pole mismatch protection. The scheme featured a 5 second definite time delay to avoid spurious tripping due to faults. Although these individual lines could have been considered as separate sources of offsite power, this event demonstrated that the lines were subject to simultaneous failure resulting from unintended operation of the relaying scheme. SRP has stated that the negative sequence relaying has been disabled and pole mismatch protection is being implemented by alternate relaying.