Tesoro Refining and Marketing Company LLC v. Pacific Gas & Electric Company,

Case No. 14 CIV 00930 (JCS)

In the United States District Court

Northern District of California

(San Francisco Division)

Expert Report of Brian Rahman, ZGlobal, Inc.

Supplemented

Respectfully submitted by:

Brian Rahman

ZGlobal, Inc.

I graduated from Washington State University in 1991 with a Bachelor of Science in Electrical Engineering. I am licensed (License No. E 14914) as a Professional Engineer in the State of California. I currently reside in Folsom, California.

I began my professional career in 1991 with Pacific Gas and Electric Company as an Operations Engineer. My primary responsibilities as an Operations Engineer was to perform power flow studies of the PG&E bulk electric system. Additionally, I was responsible for establishing operating procedures to insure the safe and reliable operation of the bulk electric system. Also during my time with PG&E I served as a Hydro Generation Engineer and Distribution Engineer. As a Hydro Generation Engineer, I provided field engineering support for PG&E's various Hydro-Electric generation facilities. As a Distribution Engineer, I was responsible for distribution engineering for substations and distribution circuits throughout Marin County, CA. As a Distribution Engineer, I was also responsible for coordination of distribution system maintenance, upgrades, and emergency restorations. My combined work history at PG&E afforded me with significant exposure and experience associated with system operations/control, protection systems, power generation operations, and overall utility practices and procedures.

In 1996 I joined the California Independent System Operator (CAISO) as a control room operator. After serving as a control room operator, with primary responsibility of issuing generation dispatch orders to participating market generators and other system resources, I served as the manager over market operations. As manager of market operations I oversaw the daily, hourly, and real-time markets administered by the CAISO. I concluded by time with CAISO as the Program Manager of their Market Redesign and Technology Update (MRTU) project.

I am currently employed by ZGlobal Inc. where I am an executive director and function as a principal consultant on electric utility operations, design, and policy matters. I joined ZGlobal in 2006.

During the past 10 years I have not authored any publications; and nor have I provided testimony as an expert witness within the past 4 years.

With respect to the Tidewater outage and legal action against PG&E, I have been retained by the Tesoro Refining & Marketing Company to provide expert testimony pertaining to the November 10, 2010 unplanned power outage at the PG&E Tidewater Substation. ZGlobal charges Tesoro an hourly rate of $375.00 for my work on this matter. However, my compensation for providing this expert testimony is limited to my existing salary with ZGlobal. I have no personal financial incentive or personal benefit associated with these legal proceeding regardless of their outcome. The contents of this report are based on my technical knowledge, previous utility experience, and various documents I have reviewed associated with this case.

Statement of Opinion:

On November 10, 2010 PG&E experienced an unplanned outage of the Tidewater substation causing loss of electrical power to PG&E distribution load in Concord, PG&E Cogen Customer Foster Wheeler Martinez (FWM), and the Tesoro refinery. The unplanned outage was the result of a series of actions, or lack of actions, by PG&E. Within the following report, I will address the following elements:

1. PG&E had advance knowledge and understanding of islanding risk at Tidewater;
2. PG&E's failure to address possible islanding condition at Tidewater;
3. PG&E's failure to install adequate protective devices on its synch switches;
4. PG&E's failure to properly operate synch switches per approved switching order;
5. PG&E's failure to detect loss of either transmission line or notify FWM;
6. PG&E's failure to notify FWM of disabeling Under-Frequency Load shedding at Tidewarer.

The unplanned outage, subsequent electrical islanding of PG&E Concord load along with FWM Cogen; and the Cogen outage were the result of PG&E substation protection design, mis-operation of synch switches, lack of adequate communication, substandard control equipment at Tidewater, and PG&E failure's to timely identify and report the loss of the transmission sources feeding the Tidewater substation.

- PG&E had advance knowledge and understanding of electrical island risk at Tidewater

PG&E understood the implications to FWM, in the event that Tidewater substation was islanded. As early as April 2010, a PG&E operations engineer had identified the islanding risk at Tidewater. The islanding risk was identified in the process of assessing clearance of SW 276 at Tidewater, which results in a single source condition for Tesoro. PG&E issued an internal "Load at Risk Notification" stating that "The majority of the time, loading at Tidewater will exceed generation at Foster Wheeler, and will likely cause Foster Wheeler units to trip offline":

> 3a. Worst Contingency #3: Tidewater-Sobrante 230 kV line
> 3b. Limiting Element #3: Tidewater Banks #1 and #2 and Foster Wheeler are out of service or islanded. Under/over voltage and under/over frequency can result. The majority of the time, loading at Tidewater will exceed generation at Foster Wheeler, and will likely cause Foster Wheeler units to trip offline.
> 3c. Report off clearance and restore load on Pittsburg-Tidewater 230 kV line. If an islanding situation occurs and voltages/frequency can be brought to tollerable levels, report off clearance and synchronize with island.

(PG&E 0000872 – Excerpt from Load at Risk Notification)

And this LAR was broadly distributed within PG&E. Accordingly, PG&E operations engineering was aware of the adverse impacts to FWM and by default the Tesoro refinery should an island condition occur. Further, on October 29, 2010, roughly 12 days in advance of the planned outage on November 10, 2010, PG&E

issued internal notice, this time an Application for Work[1], which again identified the risk of islanding and likely loss of FWM generation, associated with the November 9th-10th work. Per the Application for Work[2]: "The majority of the time, loading at Tidewater will exceed generation at Foster Wheeler, and will likely cause Foster Wheeler units to trip offline post contingency."

As stated by Sebastian Fiala in his deposition[3] the Tesoro load and FWM generation was modeled in the basecase used to perform system studies in advance of the clearance. Such loads would have been modeled to reflect the expected load and generation conditions. The implication of this mismatch, as predicted by Mr. Fiala and noticed to PG&E management and operations in the LAR notification and Authorization for Work, is the tripping of FWM generation and subsequent loss of power to the Tesoro refinery.

As Mr. Van Remoortere stated in his deposition[4], the Load at Risk notifications were used to increase PG&E situational awareness. Such information allows for advanced knowledge and preparation time to plan for possible loss of load for PG&E and Customers. PG&E, following good utility practice, had the duty to inform its transmission customer FWM of the identified risk so that FWM could take appropriate precations. However, there appears to be no evidence that PG&E acted upon the information. Mr. Van Remoortere went on to explain that identification of islanding and/or transmission customer impacts were uncommon to see in LAR notifications. Mr. Van Remoortere stated that he would review hundreds of LAR notifications during a given year and that it is uncommon to see identification of a possible island and that the island may not survive.

As an operations engineer at PG&E, I was personally responsible for performing pre-outage clearance studies similar to those done by Sebastian Fiala. I am in agreement with the assessment of Mr. Fiala that in the event both 230 kV sources to Tidewater are lost, an electrical island would form consisting of PG&E concord load, Tesoro refinery load and FWM generation. Moreover, I find the assessment of Mr. Fiala that the island would likely not survive due to the load vs. generation capacity mismatch to be sound and accurate.

The system model used by Mr. Fiala for the purpose of assessing potential impats to the electric system included specific values for FWM generation, PG&E Tidewater load, and Tesoro Refinery Load. The

[1] PG&E 00007655
[2] PG&E 00007656, bottom of page.
[3] Fiala Depostion, 55:25- 56:5
[4] Michael Van Remoortere Depo., 240.

table below shows these values, provided by PG&E[5], as reflected in the PG&E Transmission Planning modle representing the Greater Bay Area for the summer of 2010.

PG&E 2010 Greater Bay Area Transmission Planning Model - Tidewater Substation Data		
Description	**Load (MW)**	**Generation (MW)**
PG&E Tidewater Distribution Bank 1 Load	55	
PG&E Tidewater Distribution Bank 2 Load	47	
Golden Eagle (Tesoro) Refinery Load	95	
FWM Generation		125
Total:	**197**	**125**

The data above, used buy Mr. Fiala, reflects the FWM generation operating at its maximum nameplate value of 125 MW. This maximum reflects the installed capacity for each of the three generating untis with individual ratins of 35 MW, 45 MW, and 45 MW. The total load interconnected to the Tidewater substations was modeled at 197 MW. The total load to generation mismatch for the tidewater substation as modeled by PG&E was 72 MW. With this data, and assumeing an island event at Tidewater, the only logical conclusion is that the island would fail due to the excess of load well above the generation capacity available within a Tidewater substation island. In fact, given that the estimated mismatch is equivalent to nearly 58% of the total installed generation capacity, there is no other justifyable conclusion, but to anticipate that FWM generation would trip off line if the island condition occurred.

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- <u>PG&E Failed to adequately address and plan for possible island condition at Tidewater, violating "Good Utility Practice."</u>

Utilities, such as PG&E, use control centers to provide around-the-clock monitoring and control of their transmission and distribution assets. These control centers are staffed with experienced operators with the primary responsibility of monitoring the interconnected electric system, approving work to be performed to electric system components, approving work start/end times, and responding to emergency or abnormal condition to the electric system. Correspondingly, PG&E's Grid Control Center (GCC), was provided advanced notice of the planned Tidewater maintenance, and was in fact alerted to the risk of islanding and the likely outcome if an island condition was to occur. As discussed above, the Load at Risk

[5] E-mail from Laurie Edelstein to Robert Begland, Oct 21, 2015, 7:41 PM, Subject : Tesoro v. PG&E: Follow up to Brian Rahman Deposition.

notifications and Application for Work documents were provided to the Grid Control Center so that overall situational awareness of the work and risk would be well known by the PG&E system operators.

Add paragraph referenceing e-mails that prior communicaions tool place why not in the island possiblitiy. Given past info exchange and maintence corrodinated.

On October 29th, the PG&E control center was alerted to the November 10th planned work at Tidewater and its associated risks to FWM generation when they received the Application for Work[6]. Following is an excerpt from the Application for Work:

> **3a. Worst Contingency #3: Pittsburg-Tidewater 230 kV line**
> **3b. Limiting Element #3: Tidewater Banks #1 and #2 and Foster Wheeler are out of service or islanded. Under/over voltage and under/over frequency can result. The majority of the time, loading at Tidewater will exceed generation at Foster Wheeler, and will likely cause Foster Wheeler units to trip offline post contingency.**
> **3c. Report off clearance and restore load on Pittsburg-Tidewater 230 kV line. If an islanding situation occurs and voltages/frequency can be brought to tollerable levels, report off clearance and synchronize with island.**

(PG&E 00007655 - Excerpt from Applicaton for Work)

A key aspect of the PG&E Grid Control Center is to provide the single point of contact (i.e. incoming and outgoing communications) for all entities associated with the electric system, including 3rd party customers as well as PG&E staff performing routine or emergency work. The importance of communications with respect to operation of the Bulk Electric System[7] is underscored by the Federal Energy Regulatory Commission (FERC)[8] in March of 2007 in Order 693. Specifically, FERC states "communications protocols need to be tightened to ensure Reliable Operation of the Bulk-Power System. We also believe an integral component in tightening the protocols is to establish communication uniformity as much as practical on a continent-wide basis. This will eliminate possible ambiguities in communications during normal, alert and emergency conditions. This is important because the Bulk Power System is so tightly interconnected that system impacts often cross several operating entities' areas".

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[6] PG&E 00007655 - 00007657

[7] NERC defines the Bulk Electric System (BES) as including all resources that connect to the grid at 100 kV or higher, any black start units regardless of size, and all generating resources that have a gross individual nameplate rating greater than 20 MVA or aggregate facility nameplate rating greater than 75 MVA. The current definition of the Bulk Electric System (BES) can be found by searching the following site: http://www.nerc.com/pa/RAPA/Pages/BES.aspx

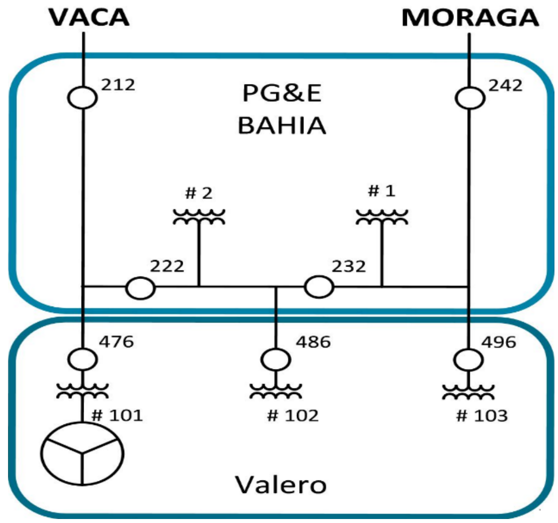
[8] See Docket No. RM06-16-000; Order No. 693. Mandatory Reliability Standards for the Bulk-Power System, Paragraph 532.

In my opinion, the Grid Control Center, with emphasis from FERC, had opportunity, responsibility, and a requirement to communicate the risk of islanding to FWM and Tesoro. Good Utility Practice as defined by NERC[9] states in part: "Good Utility Practice" shall mean any of the practices, methods and acts engaged in or approved by a significant portion of the electric industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition".

It is reasonable to expect, given the Load at Risk notifications and Application for Work, that Good Utility Practice would have included PG&E communications with Foster Wheeler and/or Tesoro, and planning for such an event. However, PG&E corporate witness, Mike Van Remoortere stated in his deposition that no action was taken to address the islanding risk[10]. This is difficult to understand when one considers that the issue was identified by PG&E's Sebastian Fiala in LAR notifications many months in advance of the November 10th outage, as well as to PG&E GCC in the weeks preceding the outage in the Application for Work. In my opinion, it would have been appropriate and in line with Good Utility Practice for PG&E to discuss this issue with FWM and/or Tesoro so that appropriate actions could have been taken by FWM. Had FWM been notified they could have taken steps, such as disconnecting from PG&E system and balancing refinery load with FWM generation.

In substations similar to Tidewater, where PG&E customer load and 3rd party generation may become islanded, PG&E has installed a Special Protection Scheme (SPS). An example of this is the Bahia/Valero SPS which prevents islanding when both of its 230 kV transmission sources are lost. Bahia is the PG&E distribution substation and Valero includes refinery load and generation. Both are served from a single looped 230 kV line similar to Tidewater:

[9] Docket No. RM02-1-000, Additional Comments of the North American Electric Reliability Council Requesting Modification and Clarification of Proposed Reliability Requirements, Pages 12 and 13
[10] Mike Van Remoortere deposition, 88-89.



The diagram above is a simplified depiction of the PG&E Bahia and Valero (Customer) 230 kV substation configuration. SPS is used to prevent electrical islanding to PG&E Bahia load and Valero generation. To prevent islanding at Bahia PG&E has implemented the following:

1. When both Bahia Circuit Breakers 212 and 242 (line side breakers) are open, all high side Valero Circuit Breakers 476, 486, and 496 will open and lockout. (Lockout is a state in which the circuit breakers will not attempt to automatically re-close).
2. When 230 kV bus voltage at Bahia drops below 15 kV (or approximately 6.5% of normal), all high side Valero Circuit Breakers 476, 486, and 496 will open and lockout

In the event both 230 kV sources into Bahia are lost (i.e. CB 212 and CB 242 are open), the Bahia/Valero SPS automatically separates the generation and refinery load (i.e. opening CB 476, CB 486, and CB 496).

Given the SPS for Valero, I believe PG&E understood the impacts of islanding at substations such at Tidewater. PG&E had advanced knowledge of electrical configuration and associated load but failed to take actions to prevent the situation identified by their own operations engineer. But PG&E did not share the islanding risk with Tesoro or Foster Wheeler – or this potential solution to it – prior to the November 10, 2010 outage. Instead, PG&E waited until after the outage to suggest that a special protection scheme be installed.

PG&E's failure to take any steps – to include communicating the islanding risk to Foster Wheeler or Tesoro, or to communicate the solution of a special protection scheme to address local customer load – violates Good Utility Practice. And I believe that PG&E failure to do either of these things was a substantial factor in causing the outage at the Foster Wheeler cogen. Had PG&E shared its detailed analysis with Foster Wheeler, or suggested that a special protection scheme be installed, I think it is unlikely that an outage would not have occurred at the Foster Wheeler cogen on November 10, 2010.

- PG&E failed to install adequate protective devices on its synch switches and was aware of this prior to Nov 10, 2010 outage, violating its own design standards, public law, and Good Utility Practice.

A Synch switch is a hand-operated switch located within a control room, Tidewater control building in this case, used for checking voltages of transmission equipment prior to paralleling (i.e. re-connecting) disconnected electrical elements. The synch switch, when turned to the "on" position energizes a control circuit that indicates the voltage associated with the specific point in the substation. The operator must verify the voltages on either side of the circuit breaker prior to paralleling (i.e. closing the breaker). There will be a unique synch switch for each circuit breaker in the substation.

As noted above, there will be a unique synch switch for each circuit breaker[11]. Consequently, in the case of Tidewater, there are three (3), one each for circuit breakers 212, 232, and 202. When operated, the voltage will be presented to the operator on the voltage meter below the Synchroscope[12]. An important fact to understand is that there is only one Synchroscope at Tidewater. This is because, as in most substations, only one switching operation is performed at a time. Moreover, the control circuits are designed and configured to read only one potential device[13] (i.e. voltage) reading at a time. Consequently, the standard design[14] for the synch switch includes a special faceplate with interlocks that prevent more than one synch switch from being in the "on" position.

To further prevent the inadvertent paralleling, (i.e, engaging more than potential device within the same control circuit) of the potential devices, there is only one synch switch control handle available in the control room.

[11] See Pictures PG&E00026696

[12] See Pictures PG&E00026706

[13] See Picture PG&E 00026729 and 00026730 (bushing mounted potential device is in the grey insulators nearest the photographer. Name plate is blow up of small silver plate on box below insulator)

[14] PG&E 00026142, PG&E Electrical Design Standard, Requirements for control switches for distribution substations

(PG&E00026696 - Tidewater CB 232 Control Panel at Tidewater. Note: synch switch has key, with red removable handle in left hand side of picture).

Whereas in the companion Circuit Breaker 212, there is no key in the synch switch:

(PG&E 26694 - Circuit Breaker 212 Control Panel at Tidewater Substation. Note absence of Snyc switch control handel).

Note sync switch (above and to the left of CB 212 control switch with red and green lights) is missing the red control handle because it is in the CB 232 synch switch at the time these photographs were taken.

The control switches, specifically the synch switches, at Tidewater did not meet the PG&E design standard[15]. Much of this information was revealed in the written work papers provided[16]. As Ben Nie discusses[17] the synch switch design is a special specification that was not properly followed:

> "Electroswitch Part No. 2424LD was a special spec developed to allow compatibility with the GE SB1 style synch switch, which was predominant in the PG&E system at the time. The 2424LD contains only the switch itself, with No handle, and No nameplate. A GE nameplate (which contains the notch required for keying) was required to be ordered to be used in conjunction with Electroswitch 2424LD, and the GE handle would also be

[15] PG&E Requirements for Control Switches, PG&E 26142
[16] PG&E 732, Root Cause Analysis, PG&E 18814
[17] PG&E 10126 e-mail .

used. If the 2424LD were to be applied with an Electroswitch nameplate, the keyed notch would be missing, and thus there would be no locking mechanism in the "On" position.

I'm wondering if individual project engineers may not have the time to read through the detailed descriptions of every item on the BOM and this could be missed, as it would not be intuitive to order a GE faceplate to go with the Electroswitch switch without prior knowledge of the history."

As noted by PG&E senior protection engineer Karchemskiy[18] "Synch switches at the station are not keyed. This is serious violation of PG&E standard design. It allows paralleling of PT secondaries, which is abnormal":

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Jonathan:
I got your message. Here is a summary based on the information we have so far:

Tidewater breakers tripped as a result of misoperation of station automatics. It made a
false Power Fail decision. There is no indication that remote terminals at Pittsburg and
Sobrante ever tripped. The problem was local to the station.

Automatics scheme consists of PTs, secondary wiring and controller. So far the following
problems have been identified:
1. Sync switches at the station are not keyed. This is a serious violation of PGandE
standard design. It allows paralleling of PT secondaries, which is abnormal.
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(PG&E 18814)

PG&E's Richard White also agreed with this statement, as reflected in his deposition,[19] when asked "Would you agree that the absence of a mechanical interlock on the synch switches was a serious design deficiency?" Mr. White's reply was "I would say yes".

The Tidewater outage was investigated by the California Public Utilities Commission (CPUC). CPUC documented their investigation and issued an Incident Investigation Report[20]. Associated with the CPUC investigation were responses to data requests[21] provided by PG&E, including the following question and response regarding synch switch design and the absence of a mechanical interlock:

[18] PG&E 18814, email from Feliks Karchemskiy, Exhibit 13
[19] RW P 56 line 22 – P 75 line 8
[20] TRMC 7361-7363
[21] CPUC Data Request DR1111301, PG&E 00012348

Question 2: Did installation procedures at the time require the installation of the keyed handle failsafe mechanism?

Response: Yes, the keyed handle failsafe mechanism was required when the switches were installed in 1985/1986.

Response provided by: Chung Lam, Senior Consulting Electrical Engineer, Substation Engineering

(PG&E 00012348).

Based on this information, the CPUC determined that PG&E was in violation of General Order 95 Section III, 31.1 due to the incorrect synch switch installation. The CPUC issued the following conclusion associated with their Incident Investigation Report for the Tidewater outage[22]:

> "Standard PG&E synch switch installation requires a mechanism (a keyed handle) to prevent multiple synch switches from being in the "on" position simultaneously. PG&E did not have this mechanism installed on the synch switches for circuit breakers 202, 212 and 232 in Tidewater Substation. When PG&E examined the switches after the incident, they found that switches for breakers 212 and 232 were both in the "on" position. PG&E concluded that this was a contributing factor to the incident. Because the improper installation of the switches contributed to the incident, PG&E is in violation of CPUC General Order 31.1."

General Order 31.1 (Design, Construction and Maintenance) states: "Electrical supply and communication systems shall be designed, constructed, and maintained for their intended use, regard being given to the conditions under which they are to be operated, to enable the furnishing of safe, proper, and adequate service. For all particulars not specified in these rules, design, construction, and maintenance should be done in accordance with accepted good practice for the given local conditions known at the time by those responsible for the design, construction, or maintenance of communication or supply lines and equipment."

I agree with the CPUC, as well as with PG&E senior protection engineer, that the installed synch switches at Tidewater substation did not meet the design standard and failed to include the required mechanical interlocks. Moreover, I agree with PG&E's assessment that this is a serious design violation which allowed for paralleling of the PT secondaries, violating Good Utility Practice.

[22] TRMC 7363, Conclusion.

Additionally, PG&E was aware that the synch switches did not include the mechanical interlocks prior to the unplanned outage at Tidewater[23]. Around March 2010, PG&E performed a "walk down" of the Tidewater substation[24]. The "walk down" was in conjunction with PG&E planned upgrades referred to as "MRTU Upgrades" and occurred in 2010 prior to the unplanned outage. A "walk down" is basically "a pre-construction site visit where planned construction is discussed by design engineers, protection engineers, and construction and maintenance people involved."[25] During this walk down, PG&E personnel were informed of the synch switch issue[26] by the Tidewater substation supervisor Mr. White. Mr. White has extensive knowledge and experience with the Tidewater substation and has physically operated the synch switches in question causing him to have personal knowledge of the ability to operate more than one synch switch at a time[27]. However, as conveyed by Richard White[28] in his deposition, he could not recall there being any sense of urgency from the group involved in the walk down to address the serious design issue.

Although noted as an addition to be included in the MRTU Upgrade by Ben Nie in a December 2010 e-mail to Jonathan Sykes,[29] it does not appear to have been added to the MRTU work effort prior to the November 2010 outage. My review of the MRTU Upgrade project materials[30] did not find any reference to new synch switches or resolution to missing mechanical interlocks. In my opinion, this is a serious oversight, especially given that the synch switch issue at Tidewater was noted by Richard White to be the only PG&E substation he was aware of that lacked the standard mechanical interlocks[31].

PG&E was aware of the synch switch issue at Tidewater prior to the outage, yet failed to take any action – much less urgent action – to correct them. Had PG&E simply taken a basic step of posting a note on the control panel alerting the operator to the issue, miss-operation of the synch switches may have been prevented, even without the mechanical interlocks.

It is my opinion, based on the information provided and my engineering experience, that the synch switch issue at Tidewater was most likely the cause of the unplanned outage of November 10th.[32] Failure of

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[23] Richard White Depo., 50:22-25.
[24] Richard White Depo., 41:9 – 18.
[25] Richard White Depo., 30:11-14.
[26] Richard White Depo., 52:1-25.
[27] Richard White Depo., 51:23 – 52:11.
[28] Richard White Depo., 54:1 – 8.
[29] PG&E 00026668, e-mail from Ben Nie on 12/13/10 at 1:14 PM.
[30] PG&E 00026671 – PG&E 00026680
[31] Richard White Depo., 43:22-44:2.
[32] As with any alternating current (AC) electrical circuit, current will flow, following the path of least resistance. In a perfectly balanced system, including potential devices and associated control wiring (i.e. consider CB212 potential transformer and control wiring running from device to control panel in control building as one control circuit and CB232 potential transformer and control wiring running from device to control panel in control building as a separate circuit) the impedance of the two separate control circuits would be the same. In this perfect theoretical condition,

PG&E to address a known design violation enabled two synch switches to be left in the "on" position, which likely resulted in damage to the potential transformers. PG&E, in their root cause analysis, determined that the potential transformers associated with the circuit breakers that operated (i.e. unplanned operation of CB 212 and 232 at Tidewater) were both in error and providing inaccurate measurements.[33]

- <u>PG&E operators failed to properly operate synch switch, per PG&E Work Procedure TD3320P-18</u>

In their Root Cause Analysis of the November 10, 2010 Tidewater outage PG&E found that synch switches for Circuit Breakers 212 and 232 had both been left in the "on" position. Referencing PG&E switching logs for work that was performed on November 9th, 2010[34] it can be seen that CB 212, and its corresponding synch switch, were operated at 1643 hours (see operation number 59). This appears to be the last time, prior to the unplanned outage, that the synch switch for CB 212 would have been operated and erroneously left in the "on" position. The switching log for November 10th, 2010[35] shows the steps taken by PG&E operator associated with CB 232 (see operation number 57) to return the Tidewater – Sobrante 230 kV line to service at 1450 hours. This appears to be the last time, prior to the unplanned outage, that the synch switch for CB 232 would have been operated and erroneously left in the "on" position. Both of the above noted switching operations were performed by the same PG&E operator (Dooley).

Leaving synch switches in the "on" position is in direct conflict with PG&E work procedure for switching and performing paralleling operations. PG&E Work Procedure TD-3320P-18 requires that the operators "turn off the Synchronism Scope if it was turned on" earlier in the process:

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there would not be any circulating current due to a perfect impedance match. Circulating current is an undesirable consequence that will occur with paralleled electrical equipment when there is a mismatched impedance between the two circuits or equipment. Circulating current, especially in control circuits with potential transformers can result in damage to the potential transformer. This is precisely why the synch switch discussed above should include interlocks to prevent inadvertent paralleling of potential transformers. PG&E's Ben Nie confirms this issue and states that "more likely than not" the synch switches being left in the on position "was the cause of the substation outage" at Tidewater.

[33] In the post outage investigation PG&E discovered that potential transformers, CB 212 line side C phase, CB 232 line side C phase, and CB202 Bus D, were not functioning as expected (Root Cause analysis PG&E 00000736 bottom paragraph) In fact, the two Circuit Breakers that opened, resulting in the unplanned outage were CB 212 and CB 232 at Tidewater and these were also the two synch switches that were found to be in the "on" position resulting in both potential transformers to be in parallel operation.

[34] PG&E 00007649 – 00007654, switch log to clear and then return to service Pittsburg-Tidewater 230 kV

[35] PG&E 00006694 – 00006699, switch log to clear and then return to service Tidewater – Sobrante 230 kV

Substation Switching Procedure – Field Instructions | **Utility Procedure: TD-3320P-18** Effective: 03/18/10 Rev: 1

9. Switching within Safe Operational Ratings

Before paralleling, separating, or de-energizing equipment, busses, circuits, or portions thereof, verify that the device to be operated is equipped to perform the task safely. (1466, Attachment 1, Section 2)

10. Operating a Circuit Breaker (CB)

When operating a CB, perform the following procedure:

a. On breakers equipped for a synchronism scope, turn on the scope and note the system conditions before operating the CB.

b. Observe the amp meter while opening or closing the CB.

c. Confirm that the red/green lights indicate the desired CB condition.

d. Note the system conditions if the CB is equipped with a synchronism scope.

e. Turn off the synchronism scope if it was turned on in item10-A above.

(PG&E 00007677) (Note final step in circuit breaker operating procedure is to "Turn off the synchronism scope" which is accomplished by turning sync switch is "off" position.)

Based on the above times the two synch switches (CB 212 and CB 232) were last operated and the subsequent realization by PG&E that both switches were found to be in the "on" position during the post outage investigation, it is my opinion that PG&E operator did not adhere to approved work procedures. Moreover, the fact that the switches were left in the "on" position, counter to switching procedures but allowable due to violation of synch switch design (i.e. missing interlocks), resulted in the prolonged paralleling of the potential transformers and likely the cause of their failures as noted in PG&E Root Cause Analysis.[36] PG&E's Ben Nie confirms this opinion when questioned about the sync switches[37] . When asked "would you agree with me that the synch switches being left in the on position was more likely than not the cause of the outage?", Mr. Nie responded "I would say more likely than not, it was the cause of the substation outage." Per the sequence of events,[38] the unplanned outage and islanding of Tesoro, FWM, and

[36] The reason for this is that by paralleling the potential devices there is a risk of damage to the device. Further, the risk of damage can significantly increase if the potential devices are left in the "on" position for a sustained period of time. PG&E acknowledged that this was the consequence of what happened at Tidewater as noted by PG&E in their Root Cause Analysis: "The maintenance supervisor noted that CB212 & CB232 synch switches were both in the "ON" position on Nov. 10th, when he arrived at the substation following the outage. This would have connected CB212 & CB232's line side potentials in parallel, and bus side potentials in parallel".

[37] Ben Nie Deposition, 63:14 – 64:6

[38] Root Cause analysis PG&E00000734 Table 1 (RTScada time stamp)

PG&E Concord load occurred approximately 18 minutes after PG&E operator Dooley performed the steps to operate CB 232 returning the Tidewater-Sobrante 230 kV line to service.

- PG&E Failed to detect loss of either transmission line or notify FW in a manner consistent with good utility practices, causing the outage at the Foster Wheeler Cogen.

On November 10th, 2010, when the unplanned operation (i.e. opening) of Tidewater CB232 occurred at 15:09:24[39] PG&E operators at the Vacaville Grid Control Center failed to detect and respond to the circuit breaker operation[40]. PG&E Supervisory Control and Data Acquisition (SCADA) log from the GCC includes an entry at 15:10:04 indicating that a level 8 (highest level) alarm was issued showing Tidewater CB232 Open. This alert message should have been acknowledged by the GCC transmission operator. Moreover, had this alarm been observed, the system operator could have alerted crews to the trouble and notify FWM of being in a single source condition.

At 15:59:39 the SCADA log indicates another level 8 alarm, this time showing that Tidewater CB 212 in open position. At this point, Tidewater substation was disconnected from the PG&E bulk system and in an island condition with FWM generation, Tesoro refinery and PG&E Concord load. Again, this was an alarm and system condition that was the responsibility of PG&E GCC operators to detect and respond to.

Roughly 10 minutes after islanding the Tidewater substation (16:10 hours) the GCC was notified by the East Bay Distribution Operations (DO) stating that all breakers at Tidewater are open. This is the first indication or point in time that the GCC was aware of the situation at Tidewater.

The failure of the GCC to identify loss of either 230 kV transmission line is a serious issue, violating Good Utility Practice. Monitoring of the transmission system is the core function of the GCC. The fact that the local area (East Bay) DO had to notify the transmission operator (GCC) points to a serious lack of situational awareness and ability to properly monitor the bulk electric system.

Vacaville Grid Control Center was responsible for overseeing these PG&E assets and responding immediately to any unplanned change in status or availability. However, PG&E failed to notify FWM[41] and in fact simply failed to monitor their control system which would have alerted them to the issue. Had PG&E identified the outage of the first (Tidewater – Sobrante 230 kV) line and notified FWM, some 50 minutes

[39] Root Cause analysis PG&E00000734 Table 1 (RTScada time stamp)
[40] Exhibit 8.
[41] Kromer deposition, 77-80.

prior to loss of the second source (Tidewater-Pittsburg 230 kV), FWM and Tesoro would have had the appropriate time to prepare for a possible island condition.

PG&E's failure to identify the first line outage was followed by a failure to identify loss of the second 230 kV source feeding Tidewater. Unfortunately, by this time only a few minutes, approximately 3 minutes, remained before the FWM generation succumbed to the significant mismatch in interconnected load (primarily PG&E Concord load) and its generation capacity, resulting in the generation to be trip off-line by its protective controls. For a generator to remain on line in such a situation can result in significant damage to the physical generator equipment, thus the use of protective equipment to preserve the integrity of the generator and its ability to return to service in an expeditious manner once forced off line. Alternatively, the generator may experience damage and become unavailable for a prolonged period of time to make repairs.

Although there was limited time after loss of the second source, FWM would have had an opportunity to manually isolate themselves and the Tesoro refinery had PG&E altered them to the situation. As stated by the plant manager, had they been notified they would have responded to the situation and manually opened their tie-breakers (CB 472 and CB 482) isolating FWM and Tesoro from the PG&E grid. Had a notification occurred immediately upon loss of the first 230 kV source into Tidewater, FMW and Tesoro would have had time to adjust and plan for possible loss of the second source. However, as there was no notification this opportunity was lost.

- PG&E's failure to notify FWM of disabeling Under-Frequency Load shedding at Tidewarer Substation

Under-frequency load shedding is implemented as an automated function designed to arrest under-frequency deviations before interconnected generation is tripped off line by protective relaying to prevent physical damage to the generator. In 1986, during technical discussions regarding freqeucny relaying, PG&E informed FWM that:

PG&E's "Load Shedding and tie Tripping Schedule" indicates tht all interruptible customers and 50% of the remaining load will be shed automatically…[42]

[42] PG&E 00022716

Per PG&E Sinle Line Meter and Relay Diagram for Tidewarter Substatoin[43] under frequency relaying was included at Tidewater and is indicated on the drawings at device"81" with apparent trip signals send to the 21 kV Bus section "F" for load shedding. However, as observed during the Tiedwater substation inspection, the Under-Frequecny Load Shedding at Tiedwater had been cut-out of service. The actual date and time these devices were removed from servie is unclear.

FWM had reasonable expectation, give correspondence druing 1986, that some level of load shedding would occur at Tidewater. In fact, they were under impressing that at least 50% of the concord laod wouls be shed during an underfrequency event. However, when PG&E unilaterally removed the tidewater under-frequency load shedding from service they failed to update this information to FWM.

Although there is no guarantee that under-frequecy load shedding of PG&E Concord would have allowed the FWM generation to sustain the Tidewater island that occurred on November 10th, it wouls have certainly increased the possibility. Moreover, had FWM been provided an update to the information initially provided in 1986, they would have been affored an opportunity to assess the increased risk of total power loss should an island event occure as predicted by PG&E engineer Sabasian Fiala.

Conclusions

The November 10, 2010 Tidewater outage was the result of a series of actions and lack of actions taken by PG&E in the months and minutes leading up the unplanned outage. PG&E understood the implications and impacts to FWM in the event an island condition occurred. Specifically, they understood that there was a high likelihood that FWM would trip off-line. However, PG&E took no actions to address the risk of islanding. Further, PG&E understood that Tidewater substation synch switches were not standard and did not include the required mechanical interlocks preventing parallel operation of potential transformers. Had PG&E taken basic action, such as posting a notice on the Tidewater control panel alerting operators to the risk of operating more than one synch switch, they may have avoided the erroneous use of the synch switches. However, this was not done and a PG&E operator at Tidewater incorrectly operated the sync switches by leaving two of them in the "on" position. This situation is likely

[43] PG&E 00001101

the cause of the failed potential transformers. Finally, compounding the impacts further, PG&E Grid Control Center Operators failed to respond to one and then a second system alarm alerting them to the outage.

The initial design violation of the synch switches and subsequent lack of action to address the possible islanding event set up the conditions for the unplanned outage. The synch switch design violation allowed the operator to make an error in performing the operation of the synch switches. Once the islanding condition occurred, PG&E's lack of attention / situational awareness compounded the impacts to FWM when they failed to detect the first outage. It is my opinion that the combination of these events and actions resulted in the Tidewater outage and subsequent impacts to the Tesoro refinery.

As stated above, there was a series of events that contributed to the cause of the power outage to the Tesoro refinery. Had any one of these been handled differently, the outage may not have occurred.

First, PG&E did not take action when alerted by their own operations engineers that an islanding condition was possible that would likely trip FMW generation. They knew of this well in advance but failed to take action such as implementing a special protection scheme similar to that at PG&E Bahia substation.

Second, PG&E did not take action to correct an erroneous installation of sync switches at Tidewater that was in violation of PG&E design standard. This design standard violation caused a situation that allowed PG&E operators to improperly operate the sync switches due to lack of mechanical interlocks. Had PG&E corrected the violation, they would have included mechanical interlocks preventing the operating error.

Third, PG&E operator failed to follow training and approved switching procedures causing the inadvertent paralleling of potential transformers. The operating error caused the potential transformers for CB 212 and CB 232 to be in parallel of an extended period of time. This is likely the cause for both of these potential transformers to malfunction. Recall these were the potential transformers found to be damaged upon post outage testing.

Fourth, PG&E Grid Control Center operators failed to detect loss of the first and then second line feeding Tidewater. PG&E's failure to respond to the first line loss into Tidewater eliminated any opportunity for FWM to prepare for an islanding condition. Their failure to detect loss of the second line and the necessity for PG&E East Bay Distribution Operations to inform the GCC of the situation is a serious lack of situational awareness.

Fifth, PG&E failed to update FWM with changes made to under-frequency load shedding at Tidewater substation. PG&E has initially informed FWM of the expected load shedding during underfrequency events but failed to update FWM when this scheme at Tidewater was removed from service.

In Summary, PG&E was aware of the possible impacts should an electrical island materialize, had available solutions to mitigate possible risk but took no action, violated both design standard and operating procedure related to installation and operation of sync switches at Tidewater, and ultimately failed to detect and respond to the unplanned outage at Tidewater. This sequence of events (lack of action and errors) established the conditions necessary for the unplanned outage of November 10th, 2010 at Tidewater which directly impacted FWM ability to remain on-line serving Tesoro refinery load. Had any one of these items been addressed it is likely that loss of power to Tesoro could have been prevented, even under an islanding condition at Tidewater.

BRIAN RAHMAN - EXECUTIVE DIRECTOR OF ENGINEERING

Brian Rahman is ZGlobal's Executive Director of Engineering. He has over 22 years of extensive experience providing precise professional applications in areas such as overall management of market systems, operations, design and technology update; project coordination in a variety of utility/energy related disciplines.

PROFESSIONAL EXPERIENCE

ZGLOBAL ENGINEERING & ENERGY SOLUTIONS (2006-Present)
Executive Director of Engineering

Brian is our resident expert in Energy Market Implementation. His engineering and technical expertise in Utility Operations in addition to his proven ability in managing large complex projects, enable him to perform both technical and project management responsibilities.

CALIFORNIA INDEPENDENT SYSTEM OPERATOR (CAISO) (1997-2006)
MRTU Program Manager and Manager of Program Office

Responsibilities included overall management of the Market Redesign and Technology Upgrade program. This program included the wholesale replacement of all Market Systems, Settlement systems and modifications to approximately 15 supporting applications as well as replacement of the underlying application architecture. Responsible for negotiations and contract relationships with multiple software vendors, service providers, and consulting firms. This was a $170 M program with a contract and staff headcount of 215 people. Role involved routine reporting and interaction with CAISO Board of Governors, FERC, and State regulators.

Manager of: Market Operations, Market Redesign & Technology Update, Special Projects, Market Engineering, Real Time Market Operations, Technical Support for Real-Time Operations

Responsible for the specification, design, procurement, and testing of Real-Time, and Residual Unit Commitment Markets. Provided management and coordination for multiple project groups engaged in the design and implementation of market applications and supporting systems. Oversaw the project requests, budgets, staffing, design documents and contract negotiations. Responsible to insure Tariff and FERC order requirements are represented in market applications and operating procedures. Other responsibilities included Department Capital and O&M Budget development, department and corporate representative for market design and technical implementation expert, oversee the Day-Ahead, Hour-Ahead, and Real-Time energy, transmission and ancillary service markets, insure close coordination with grid operations concerning system load forecast, energy and reserve procurements, insure accuracy of all published prices and settlement quality data. Insured development of detailed design documents for vendor and internally developed software, coordination of software testing and deployment with Market Participants. Project Management responsibilities consisted of overall project development including budget, design, staffing, inter-departmental and Technical Support for Real-Time Operations.

PACIFIC GAS & ELECTRIC (PG&E) (1991-1997)
Electrical Engineer, Hydro Generation, Project Engineering

Prepared job proposals that included cost estimates, engineering calculations, studies and design. Developed equipment and consulting specifications, procurement documents and evaluated proposals for electrical equipment and system revisions and upgrades. Provided engineering guidance and technical support to engineering designers and drafters. Planned, designed and developed routine work plans needed to maintain and improve PG&E hydro facilities.

Distribution Engineer

Provided electric planning and operations support for 12kV distribution network. . Performed load growth studies and developed capacity increase projects as needed for future growth. Provided protection settings for distribution breakers and line equipment to insure coordination of protective devices. Investigated and resolved power quality and voltage complaints. Served as on-call supervisor during off-hour emergencies.

Electrical Engineer, Hydro Generation

Primarily responsible for the facilities located on the Mokelumne and Stanislaus watersheds consisting of 9 powerhouses and a variety of extensive water conveyance systems. Provided construction, maintenance, and operations engineering support for PG&E hydro facilities. Identified equipment problems and developed scope, cost, design, and procurement documents. Provided technical support for maintenance activities, operational constraints, and construction projects. Provided budget input including project alternatives, economic evaluations, and justification. Served as project manager, providing project estimating, justification, schedule and cost tracking. Provided construction coordination and on site engineering. Served as on-call supervisor. Applied Reliability Center Maintenance practices to PG&E hydro facilities. Responsibilities included: Comprehensive review of hydro generation equipment maintenance practices and detailed reviews with maintenance staff, documentation of existing time based practices, and recommended condition based analysis used to trigger maintenance.

Project Coordination

Prepared job proposals that included cost estimates, engineering calculations, studies, and design. Developed equipment/consulting specifications, procurement documents, and evaluated proposals for electrical equipment/system revisions and upgrades. Provided engineering guidance and technical support to engineering designers and drafters. Planned, designed, and developed routine hydro work needed to maintain and improve PG&E hydro facilities.

Engineering Consulting

Solved electrical engineering problems, evaluated and recommended alternative solutions, evaluated equipment and engineering service bids and assisted in the project scope, evaluation and justification.

Power System Engineer

Performed contingency studies, analyzed system disturbances and coordinated switching and clearances for transmission and relay protection maintenance. Monitored system performance and developed Dispatch Operating Instructions. Reviewed transmission and generation planning projects for operational capability, relay coordination and determined impact to generation resources. Performed transformer evaluation studies for use in transformer bank re-rating project and station capability report for planning studies. Developed qualifying facility database and PG&E winter electric system base-case. Worked on procedure for Diablo Canyon Power Plant black-start.

EDUCATION & CERTIFICATIONS

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