Central Station Power Switching Characteristics

This ATM summarizes the conditions which led to the ALSEP Central Station Discrepancy Report AA 7344 and analyzes the results of troubleshooting steps performed to isolate and define the anomaly. Recommendations are made regarding proper operational procedures.

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SUMMARY

Under some combinations of operating conditions, spurious switching has been encountered in the Power Distribution Unit (PDU) during switchover from Power Conditioner (PC) #2 to #1. Analysis of the circuitry involved indicates the cause to be the slow start-up of PC #1 as a result of its integral "hold-off" circuit. This effective time delay permits decay of the voltage on the 5-volt command lines to a level simulating reception and decoding of a switching command. PROBLEM

Disabling the hold-off circuit by actuation of Astronaut Switch No. 1, a normal operational procedure, permits a fast start-up of PC #1, keeping the command lines at a high level and preventing spurious switching. SOLUTION

1.0 INTRODUCTION

During testing of the ALSEP qualification model central station (TP 2333047 Central Station Post-Assembly Verification), a deviation was performed to run an abbreviated version of the SIDE section of TP 2333033 (Experiment Integration). In the course of this deviation, there occurred a set of conditions which had not been encountered in previous tests. The conditions arose while test personnel were performing a cycle of PC switchovers (from PC #1 to PC #2 and then from PC #2 back to PC #1). After the switch from PC #2 to #1, it was noted that Experiments 3 and 4 (Solar Wind and SIDE, respectively) which had been on Standby before the PC switch were in OPERATE after the switchover. This was documented in Discrepancy Report DR 7344.

After the original discrepancy was reported, a series of troubleshooting procedures was performed. These tests, and their results, were documented via supplementary sheets on DR 7344.

Engineering review disclosed that the original tests were performed with the Astronaut switch #1 open (fully CCW). In this position the "hold-off" circuit for PC #1 is enabled which accounts grossly for the dissimilar behavior of the two switching operations, i.e. from PC #2 to #1 vs. PC #1 to PC #2.

Further tests revealed that erroneous switching in the PDU occurred only during the switch from PC #2 to PC #1 and never on the other transition. Later tests confirmed that closing Astronaut Switch #1 (rotating CW) eliminated the erroneous PDU status changes during the switch from PC #2 to #1.

It should be pointed out that the intended ALSEP operational mode has always been with the Astronaut switch #1 closed, even if ALSEP is turned on with the "hold-off" circuit enabled. This requirement had not been built into the testing sequence, and this oversight gave rise to the observed conditions.

2.0 TECHNICAL ANALYSIS

Figure 1 is a tracing from a high speed chart recording of several lines during a PC #2 to #1 transition. The top trace shows the + 12 volt output. The center shows the + 29 v line as viewed through the operating power line of Experiment #4 and the bottom is the +29 v survival line of Experiment #4. The latter two show the spurious switching resulting from the PC switchover. The time interval between switching OFF of the SURVIVAL line and switching ON of the OPERATE line is the operate time of the relay involved in the switching.

The large positive transitions on the 12-volt and 29-volt lines, depicted in Figure 1 are directly caused by the hold-off circuit, which inhibits Power Conditioning Unit (PCU) start-up until the input voltage has reached approximately 24 volts, a 50% over-voltage condition. Thus, when the converter oscillator starts, this high input voltage is reflected in a momentary 50% over-voltage on all output lines. This transient condition is <u>not</u>, however, a causative agent in the spurious switching which begins, as Figure 1 illustrates, before PC # 1 start-up.

Figure 2 illustrates the behavior of typical voltage-carrying lines during PC #2 to PC #1 switchover under different simulated RTG conditions (internal resistance variation). The effect of the hold-off circuit in permitting a prolonged decay of the voltage on the 12-volt sense line and on a typical command line is shown. By way of contrast, Figure 3 shows these same lines during switchover from PC #1 to PC #2 (Figure 3A) and during switchover from PC #2 to PC #1 with the hold-off circuit disabled by closing Astronaut switch No. 1 (Figure 3B).

These data support the following statements regarding the cause of spurious switching in the PDU during PC changeover:

1. Spurious switching is caused by decay of the "inactive" nominal 4 volts on the command lines, during the changeover period, to a level approaching that of a legitimate command.

All command lines exhibit this decay, but with a distribution of rates depending upon circuitry parts tolerances. Thus, in a given ALSEP, specific lines will consistently reach the trip level before the others and will cause the spurious switching to occur in a repeatable manner.

2. Eliminating the hold-off circuit (through actuation of Astronaut Switch #1) effectively precludes the false switching by minimizing the decay time of the command lines before the start-up of PC #1 restores the original "inactive" state voltage. This action makes the PC #2 to PC #1 switchover electrically equivalent to the PC #1 to PC #2 transition, which has consistently shown no coincident spurious switching.

3. Variation in performance among several PCU's and or PDU's is to be expected, accounted for purely by tolerances on piece parts in the circuitry; primarily the tolerance of a 1100 μfd (± 20%) capacitor.

3.0 DESIGN HISTORY

3.1 HOLD-OFF CIRCUIT

The hold-off circuit is a design requirement dictated by the lunar operational procedure of connecting the PCU to an RTG which has not reached full operating power. The purpose of the hold-off circuit is to delay start-up of the PCU converter oscillator until the RTG has attained a sufficient power capacity to support the ALSEP operational load. This delay accomplishes two desirable objectives:

a) It ensures that fully regulated operation is achieved upon start-up.

b) It ensures correct initialization of logic circuitry in the command decoder and data processor by a rapid rise to rated voltage on the PCU output lines.

It should be noted that the Power Conditioning Unit (PCU) contains redundant regulators, converter oscillators and power transformers. Further, there are other sections of the PCU, e.g. the + 12 volt sensing circuit, which are not redundant. Therefore one set of redundant sections (Regulator #1, converter oscillator #1, etc.) are appropriately called Power Conditioner #1 (PC #1) and the other redundant set PC #2. The hold-off circuit is a part of PC #1: PC #2 does not have the hold-off design feature. The relay which selects the redundant power converters is pre-set to ensure that, at time of deployment, PC #1 will be used for initial start-up with the RTG.

Without the hold-off circuit, the PCU converter would start at low RTG voltage, upon initial connection on the lunar surface. It is possible that a temporary operating mode would cause the converter oscillator to "motor-boat", going into and out of oscillation at a relatively low frequency. The effects of the rising and falling output voltages of the PCU are unpredictable. Additionally, the PCU output lines, especially the + 5 volt logic supply, would dwell at a low voltage causing further potential random status changes.

3.2 ASTRONAUT SWITCH NO. 1

The hold-off circuit was recognized as a potential single-point failure, i.e., if the hold-off circuit failed to permit converter turn-on, ALSEP could not operate. To overcome this potential failure mode, as well as to allow for contingency turn-on prior to the tripping of the hold-off circuit, e.g., in the event of a short deployment time to preclude the requirement for the LM crewmen's waiting at the ALSEP site for automatic start-up, Astronaut Switch No. 1 was included in the circuit.

This switch disables the hold-off circuit and permits ALSEP to utilize the available output of the RTG, even though the output power may be less than the desired level. With the hold-off circuit disabled, the two power converter sections are identical.

4.0 CONCLUSIONS

The spurious switching, which could occur when changeover from PC #2 to PC #1 is commanded, provided S-1 is open, should not be of concern, for the following reasons:

a) This changeover, itself, is a contingency procedure. Normal operation of ALSEP involves the use of PC #1 as the primary power converter. It is conceivable that PC #2 will not be used throughout the entire mission.

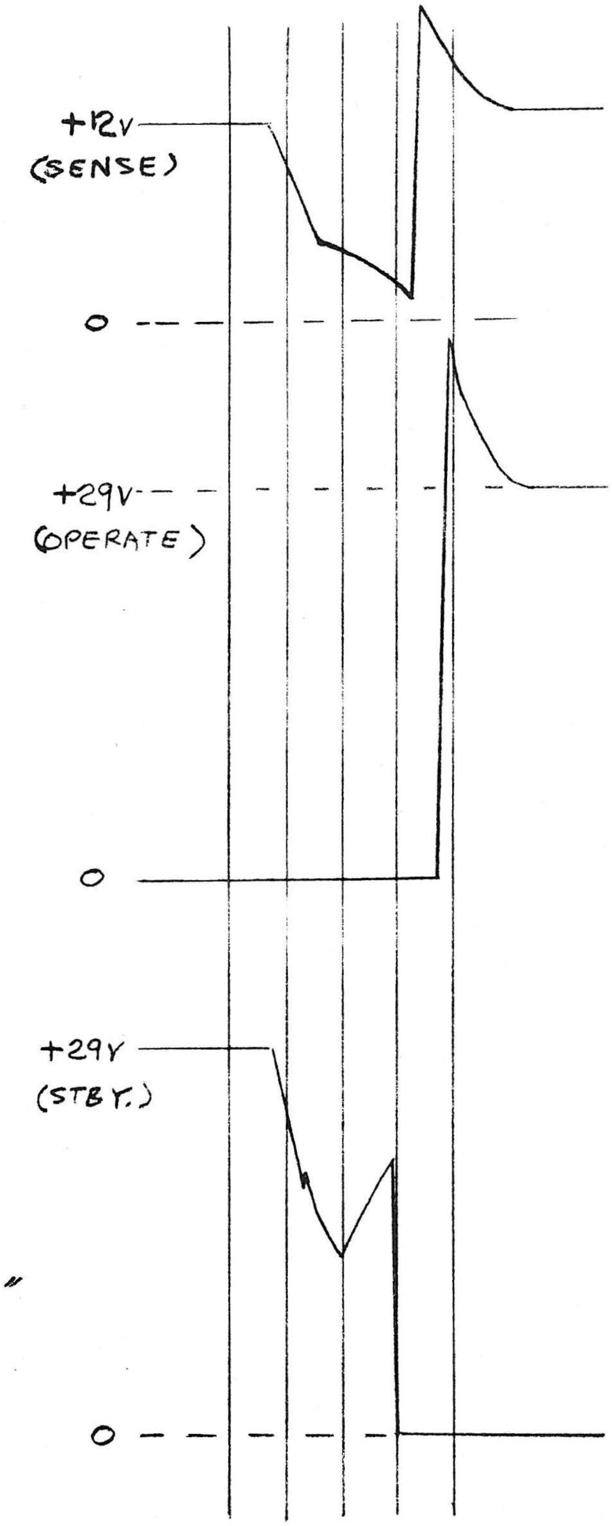
b) The spurious switching is completely precluded by actuation of Astronaut Switch No. 1. This precaution is a routine step in the ALSEP deployment procedure.

c) Even if the unscheduled switching should occur, it should not be viewed as a system failure since status changes are readily accomplished by appropriate commands.

Therefore, the only action required by the disclosure of this phenomenon is a review of all pertinent procedures, for ground tests of ALSEP operation, to ensure that provision has been incorporated for actuation of Astronaut Switch No. 1 to full CW after completion of each system turn-on and return of the switch to its full CCW position after each system turn-off. Procedures for lunar deployment should also require actuation of Astronaut Switch No. 1 at the end of the sequence.

WILL ASTRO SW BE IN NO. 1 AT L/O?
OR
IS IT SOP NOW, FOR THE CREW TO ACTUATE SW NO. 1?

CAN WE SECURE ALSEP PRIOR TO L/O WITH ~~SW IN~~ PC# 2 SELECTED?



CONITIONS
EXPT'S. 1, 2, 3 & 4 - "ON"
EXPT. CONT. #5 - "OFF"
DUMPS - OFF
XMTR A "ON"

SWITCH FROM PC #2 TO PC #1

FIG. 1

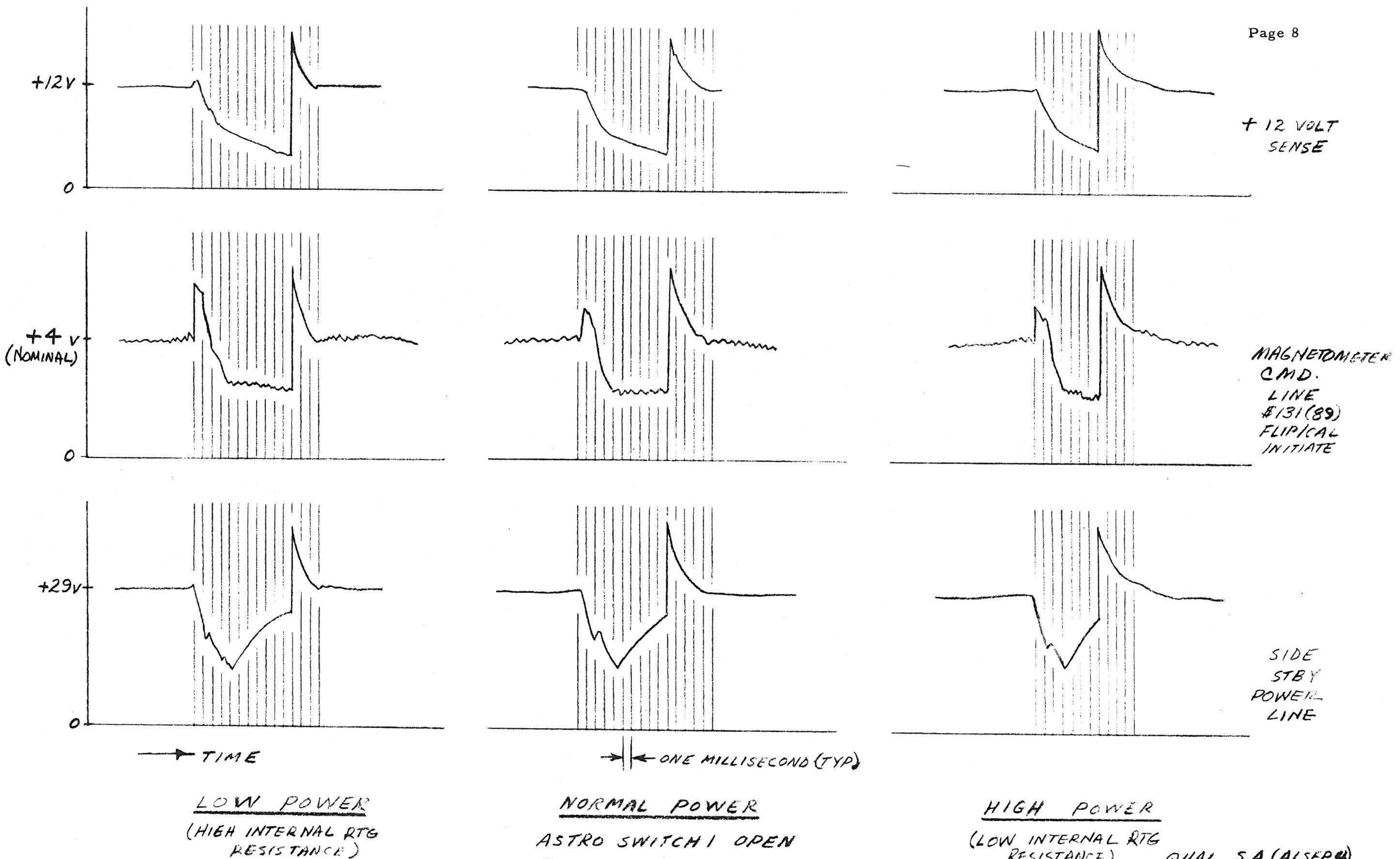


FIG. 2, PC #2 TO PC #1 SWITCH OVERS

(COPIED FROM SANBORN OSCILLOGRAPHS)

QUAL. SA (ALSEP 4)
DR 7344 PAGES 82, 84, 87
TROUBLESHOOTING
DAY 066 (3/6/68)

HEINZ
3/12/68

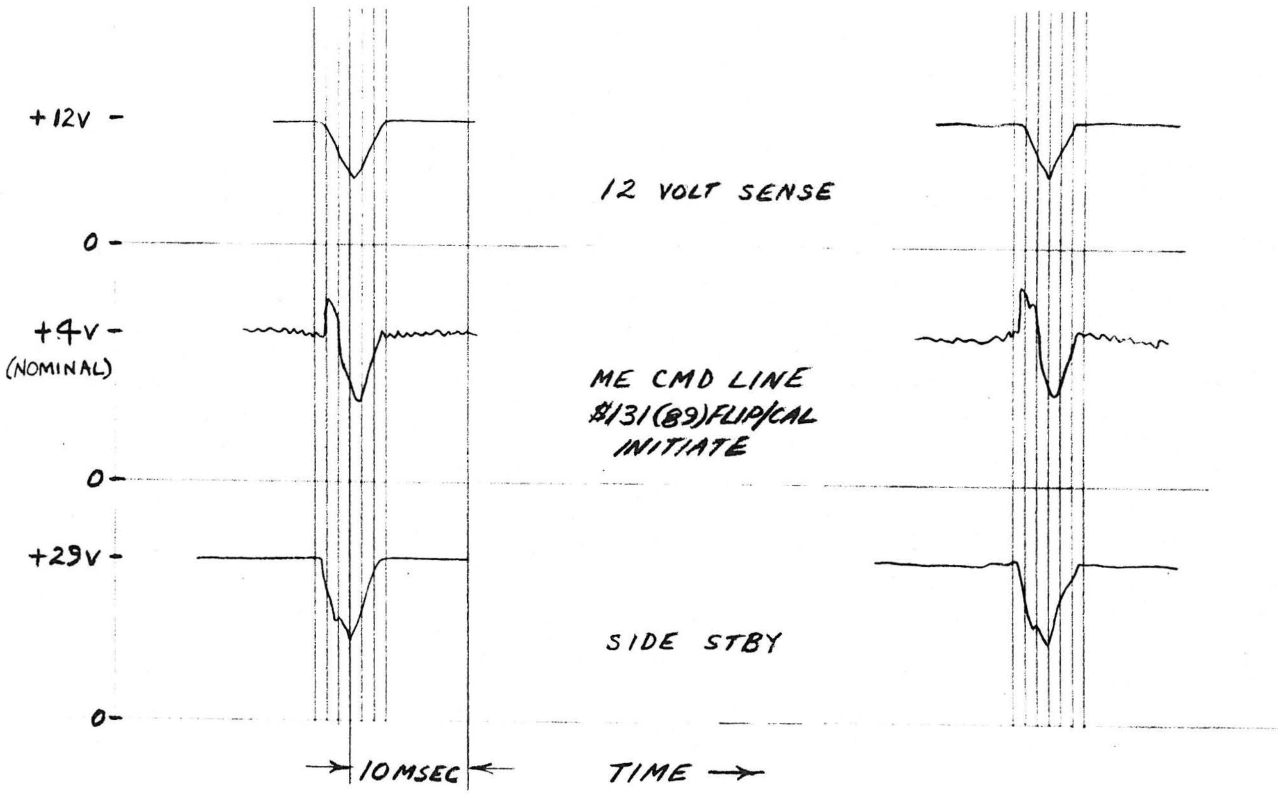


FIG. 3A, PC #1 TO #2 FIG. 3B, PC #2 TO #1

NORMAL POWER
ASTRO SW. 1 CLOSED

(CURVES REPRODUCED FROM SANBORN OSCILLOGRAPHS)
(POLAROID PHOTOS ALSO AVAILABLE)

QUAL. SA ALSEP 4
TP 2333047
PARA 6.5.6.3
DAY 067 (3/7/68)

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3-8-68