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“Load Dump” Damage to Alternators with Built-in Regulators

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AeroElectric-List message posted by: "Ned Thomas" <315@cox.net>

For what it is worth, I had an internally regulated alternator on my RV6A. I had an overvoltage occur and had no way to shut it off except land and turn off the engine. When I smelled the battery acid cooking out I was quite concerned. I was able to land before ruining the battery but even tho I immediately turned off the master when I found the voltmeter reading high, I did find that one of my strobes had fried. After this happened I installed the OV protection recommended by Bob. In the event you do encounter an OV situation you must be able to isolate the alternator. I was lucky, the battery could have blown up...

----- Original Message -----
From: "Clay R" <clayr_55@yahoo.com>

Now I see the following warning on Vans web site on the alternator page. (I think this was added this week)

Warning!

The internally regulated 60 ampere alternator should not be used with overvoltage protection systems. If you open the charging circuit while it is in operation, it will destroy the regulator.

AeroElectric-List message posted by: "Steve Sampson" <SSampson.SLN21@london.edu>

Clay - is anyone looking into this for you? It sounds like plenty of people are getting blown alternators after putting the B&C stuff on.

BACKGROUND

(1) The "B&C stuff" is only a collection of parts described in documents described in the AeroElectric Connection. Let us take care as to how the phenomenon is described with respect to implied cause and effect. ***It's not B&C's architecture but AeroElectric Connection architecture . . . B&C only sells the parts to implement it.***

(2) For years and since day-one of my participation in B&C's development and marketing of alternators, we have preached the doctrine of externally regulated alternators. Examples of this philosophy are found throughout early writings and particularly in chapters on alternators and regulators in the 'Connection. A simple inspection of B&C's offerings from the beginning will show that only externally regulated alternators are offered.

(3) There has been a lot of interest in adapting internally regulated alternators to aircraft because they are so readily available and cheap. Further, they've produced an excellent track record of reliability on cars . . . it seems a shame not exploit that characteristic in aircraft.

(4) The challenge for adapting internally regulated alternators to airplanes has always been making them behave like externally regulated alternators and generators before them. On the instrument panel there is a switch labeled ALT OFF/ON. One expects that operation of this switch will produce the same result whether you're sitting in a 1965 C-172 or a 2004 RV-8.

(5) Most alternators with built in regulators, once given the ON command via the rear-connected control wire will indeed come alive . . . but since this wire was originally intended only as a means for the EFI controller on a car to delay onset of engine loads after starting, there was no requirement for being able to turn the alternator OFF via this same wire. So, the vast majority of automotive take-offs cannot be turned OFF by removing +14v from the control wire via panel mounted switch. This condition was experienced by Mr. Thomas in the anecdote cited earlier.

(6) While the probability of regulator failure in cars is exceedingly low, ***it is not zero***. We've heard anecdotal stories of unhappy, high-dollar events taking place in airplanes after failure of an internally regulated alternator.

(7) With the goal of addressing a desire in the marketplace to utilize off-the-car technology, figure Z-24 was developed to address both ***controllability*** and ***overvoltage*** issues with the lowest practical parts count and without modifying the alternator.

RECENT HISTORY

It seems that there have been a rash of failures of internally regulated alternators installed per Figure Z-24. Let's review the inner workings and shortcomings of the modern, internally regulated alternators. We know that all alternators run best with a battery connected across their output. The battery is an excellent filter for the noise inherent on DC power generated by rectified 3-phase AC power. The battery also provides a flywheel effect . . . a kind of electrical inertia that damps out the frisky nature of an alternator's ability to quicky respond to and control its own output.

A phenomenon labeled by the automotive industry as "load dump" speaks to a characteristic native to the physics of alternator performance. Its existence has been known since the beginnings of alternator use in vehicles . . . but it was only a concern after a proliferation of solid state electronics for fuel injection systems, ignition systems, anti-lock brakes, etc. Should an alternator producing a lot of power be suddenly disconnected from the load, it may generate what would be properly called a surge of voltage exceeding bus voltage by several times. If the load dump is limited to shedding of normal system loads, the battery's electrical inertia will be in place to smooth over the event. However, if the disconnection ***includes*** the battery, no mitigating electrical-mass is present to capture a significant energy transient. In aviation parlance, a "load dump" is rapid shedding of normal system loads. The scenario we are discussing might be more appropriately called a "battery dump".

Unlike relatively low energy spikes characteristic of switching transients on inductive loads, a battery dump event is longer and carries a lot more energy. In the spring of 1998, there was a romance in the OBAM aircraft community with products called transient voltage suppressors (TVS). A school of thought suggested that the electrical system be sprinkled with these little critters to ward off effects of any gremlins of the overvoltage persuasion which may be lurking about the system. The suggested technique was to install a TVS on the power feeder for each vulnerable accessory.

There was an extensive discussion thread. You may review published excerpts of that discussion at:

http://aeroelectric.com/articles/spike.pdf

This was before we began to consider and refine any notions of using internally regulated alternators in OBAM aircraft.

In that thread, I suggested it was much better to (1) identify and mitigate such hazards at their source and/or (2) design accessories to be immune to such hazards. For decades, DO-160 has been an effective guideline for development of robust victims while MIL-STD-704 outlined design goals for output quality of power generation equipment.

Here are but a few of hundreds of relevant documents on the phenomenon to be found on the web . . .

http://www.sto-p.com/pfp/pfp-transients.htm

http://www.onsemi.com/pub/Collateral/CS3341-D.PDF

http://www.audifans.com/archives/1998/08/msg00929.html

. . . do a Google search on "load dump" and "alternator" for a wealth of useful expansion of the topic.

WHAT'S HAPPENING?

The original discussions 4 years ago focused on the need to protect system accessories from the effects of alternator behavior. In the cases before us now, the victim is NOT airframe system accessories being hammered by a skittish alternator. These are cases where the alternator is killing itself . . . or more accurately, killing its own voltage regulator.

If you look over the specifications for modern, solid state regulator chips, you'll find references to protection against load dump conditions built right onto the chip. I believe what we're observing now is a shortcoming of relatively mature automotive take-off alternators with regulators that do not enjoy this kind of protection.

Referring to the group of block diagrams in this document, note that I've illustrated 4 configurations of installation architecture for alternators with built in regulators.

(1) The first diagram is captioned "AUTOMOTIVE" and it illustrates the relationship between battery and alternator in virtually all automotive applications. The battery is ALWAYS connected to the alternator. System loads are controlled via panel switches and/or ignition switch but portions of the power distribution system are ***always hot, even when the vehicle is parked.*** Not desirable on airplanes.

(2) The second configuration is "FIGURE Z-24" referring to an architecture described in the AeroElectric Connection to accommodate two hard-and-fast design goals for using an alternator in an airplane: (a) ***absolute control*** of the alternator operation from the cockpit irrespective of flight condition and (b) protection against the very rare but potentially hazardous and expensive ***overvoltage*** condition.

(3) The third configuration describes an ill-conceived recommendation suggesting deletion of the alternator disconnect and wiring the alternator to the airplane a-la-automotive. Note that while this configuration ***prevents*** the pilot from switching an alternator off while in operation, ***it does not prevent the battery from being taken off line.*** If we disconnect the alternator from the system while leaving the battery on as allowed with Figure Z-24, only the alternator is at-risk for self destruction.

When you leave the alternator connected to the system and shut off the battery master, there is still risk of a battery-dump transient. While system loads will soak up some transient energy and mitigate amplitude and duration of the event, ***now the whole system is subjected to the transient***.

In airplanes like the Baron and Bonanza where alternators and battery master switches are separate, non-interlocked controls, switches can be manipulated in a manner that will produce the same "battery dump" effect that we're discussing. ***So the potential for this effect is not new nor is it unique to the nifty little alternators so popular in the OBAM aircraft community.***

(4) The fourth configuration illustrates an experiment to be conducted which may prove the usefulness of a technique intended to tame the dragon.

A PROPOSED GAME PLAN

(1) If you have Figure Z-24 installed and you're already flying or nearly ready to fly, don't change anything. Although you may never need the protections Z-24 offers, I don't recommend you go flying without it. It is EASY to prevent battery dump damage to the alternator by controlling sequence of operation for the switches.

[a] Battery master is the first switch to come on before cranking the engine and it should stay on until after engine shutdown.

[b] The alternator control switch may be turned on before cranking the engine but it's probably better to leave it off until after the engine is running.

[c] At the end of the flight, shut the engine down before first turning off the alternator . . . .

[d] . . . followed by turning off the battery master switch.

Following suggestions in any of the Z-figures in the 'Connection will provide you with interlocked battery master and alternator control switches wired so as to prevent an alternator from remaining on-line with the battery disconnected.

The battery dump transient is generated by the disconnection of the battery from the alternator b-lead terminal while the alternator is working hard. ***It can't be working hard if the engine is not running***. The warning published by Van's is accurate as far as it goes but misses important points with respect to ***absolute operational control*** of the alternator from the cockpit and ***overvoltage protection***. So, if you don't diddle with the switch while the engine is running, your alternator is not at risk for battery dump damage and you retain both ***operational control*** and ***overvoltage protection***.

(2) If you have yet to select an alternator but need to do it soon, you cannot go wrong with installing an alternator designed for aircraft service. Alternators using external regulation are easily managed for both ***operational control*** and ***overvoltage protection*** by simply opening the field lead. This activity does not generate the battery dump transient we're discussing.

(3) I'm planning to test an alternator with built in regulation on a test stand using a fat TVS device connected as shown in the last block diagram. I'll be making measurements of worst-case transient energies and making sure that the diode we select is adequately sized to the task.

NOTE

> If anyone out there remembers the zener diode that Pelican Aviation used to stick on the back side of their alternators (some STC'd no less!) while calling it "overvoltage protection" please recall that this was neither ov protection nor was it a practical solution to the problem before us now.

After the bench testing studies are complete, I'll be looking for volunteers who are already flying Figure Z-24 alternator control schemes. I will supply a pair of TVS diodes for installation on your airplane. You will be asked to conduct a series of battery dump simulations. After the simulations, you'll be asked to install the second diode and return the first one to me for inspection.

Once we've done the repeatable experiment to demonstrate suitability of the "fix", this paper will be updated to publish the results and Figure Z-24 will be updated appropriately. In the mean time, I'll supply a copy of this paper to Van's in with the hope that it will clarify the issues and forestall some poorly founded modifications to electrical systems in the OBAM aircraft community. Please feel free to circulate this document for both its informative value and potential for critical review.

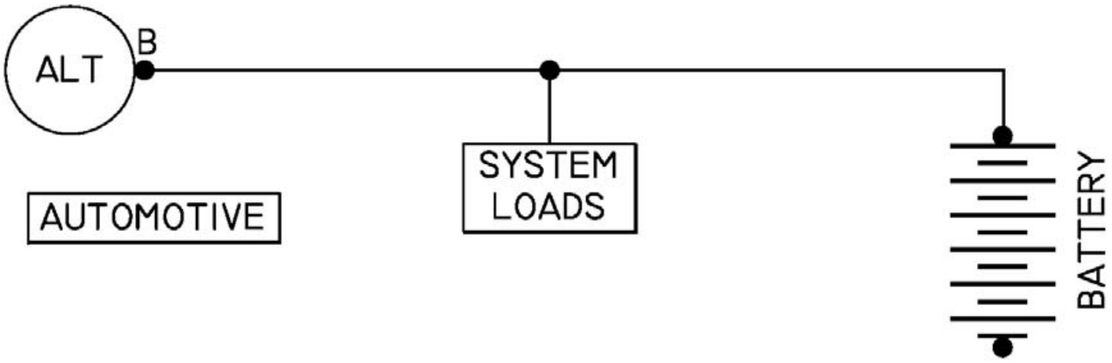
As a closing note to this document, I ran across this paper:

http://www.st.com/stonline/books/pdf/docs/4345.pdf

. . . written by the folks at SGS-Thompson on battery dump mitigation. This paper describes a proposed technique for building battery dump management right into the alternator . . . what a concept! Whether or not this capability will be offered in automotive products suited to airplanes soon is hard to predict. In the meantime, it's a no-brainer to make the alternators we have work quite nicely.

The bottom line folks . . . I believe there is good value in the use of internally regulated alternators on airplanes. However, it's important that we make decisions based upon good science that helps us understand and accommodate their unique characteristics.

Bob . . .



AUTOMOTIVE

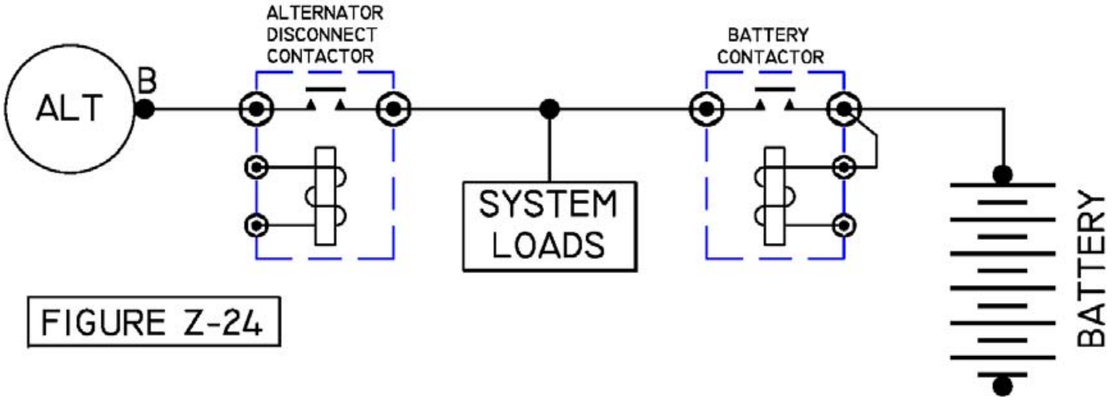
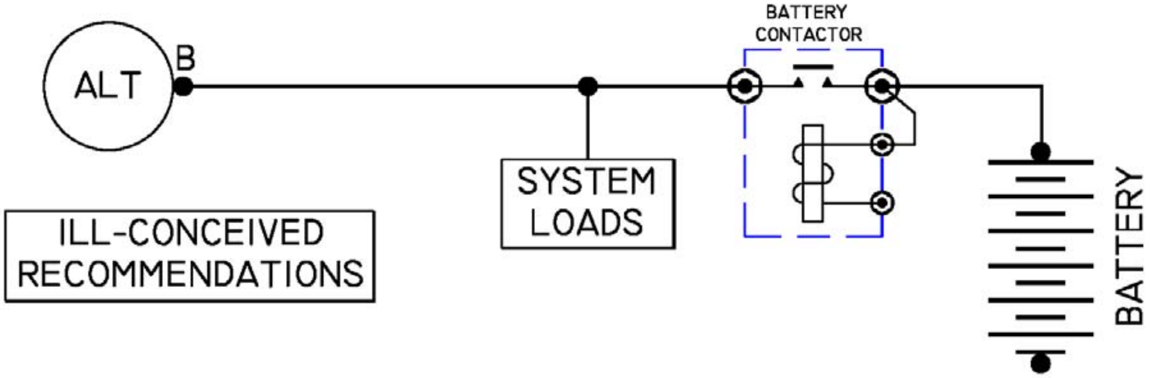
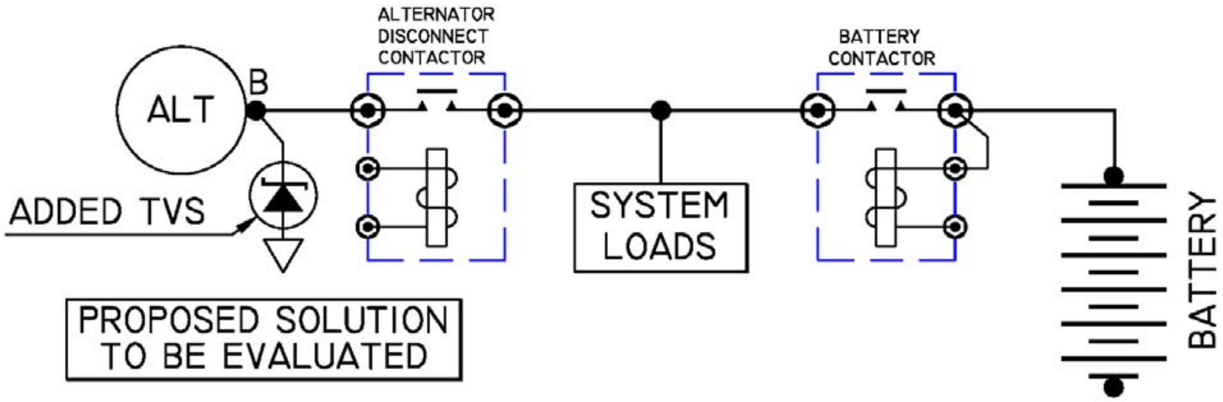


FIGURE Z-24



ILL-CONCEIVED RECOMMENDATIONS



PROPOSED SOLUTION TO BE EVALUATED