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DESIGN OF TELECOMMUNICATION LOAD EQUIPMENT PROTECTION CIRCUIT AGAINST PROTECTIVE DEVICE OPERATION TRANSIENT

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Abstract— **Network Equipment-Building System (NEBS) requirement's primary goal is to ensure that equipment can normally operate in harsh environmental conditions. This include transients that may occur on the bus due to disturbances introduced by protective devices such as fuse and breakers. This is specifically important for Telecommunications Load Equipment (TLE) where downtime can impact public safety, businesses, and mankind daily routines. Existing systems protect the TLE from damage due to this transient but triggers protections causing them to momentarily turn off. To improve the existing system, a protection circuit against protective device activation transient (PDOT) was designed, developed and tested. By placing bidirectional transient voltage suppressors (TVS) and back-to-back reverse current and inrush current protection FETs at the front-end of the TLE with hot-swap IC overcurrent (OC) and overvoltage (OV) protection functions disabled, TLE was able to operate normally during and after PDOT, and thus, compliant to ATIS-0600315.2018 telecommunication standard. This supports the need for TLE that can operate in harsh environments guaranteeing safe and reliable operation eliminating downtime and its detrimental impact.**

Keywords— **TLE, PDOT, NEBS, ATIS**

I. INTRODUCTION

Telecommunication systems operate on -48V rail and under harsh environmental conditions [7]. This drives the establishment of NEBS designation by Bell Laboratories, whose specifications are maintained by the compliance agency Telcordia [10]. The NEBS requirements define the minimum goals for equipment operating characteristics, specifically, to ensure safe and reliable equipment [5]. One of these requirements which is challenged by continuous connectivity to avoid system resets during transient events is the Protective Device Operation Transient (PDOT) with test details defined in the ATIS (Alliance for Telecommunications Industry Solution) -0600315.2018 telecommunication standard [2].
PDOT waveform is shown in Figure 1. Basically, it is comprised of two parts – the undervoltage (UV) part and the overvoltage (OV) part. For the UV part, the input voltage changes from 50V to 5V for 1.5ms which is the result of the the low impedance fault to ground of a protective device connected to the distribution bus in a telecommunications facility. For the OV part, the input voltage spikes to 100V for 50µs then back to 75V for 10ms which is the result of release of energy stored in the inductance of the bus due to the opening of the protective device. These PDOT UV and OV transients may cause the TLE to momentarily shut down, or worst, be damaged impacting local to global communication [1].

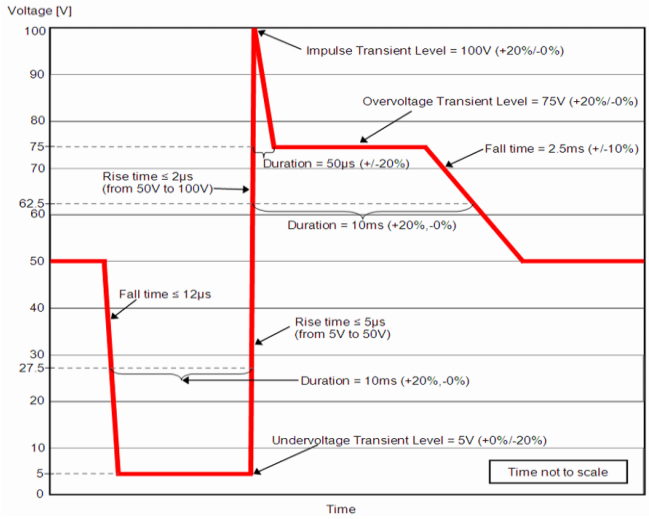

Fig. 1. PDOT Waveform

To protect the TLE from these transients, the direct solution is to apply protections such as OC and OV protection functions at the front end of TLE to block the power path to the downstream circuitry. However, this causes non-conformance to standard which require the equipment performance to not be degraded or affected by the application of the transients. In other words, the network equipment must remain in normal operation during and after PDOT.

II. PROPOSED SYSTEM

The block diagram of the proposed system is shown below:

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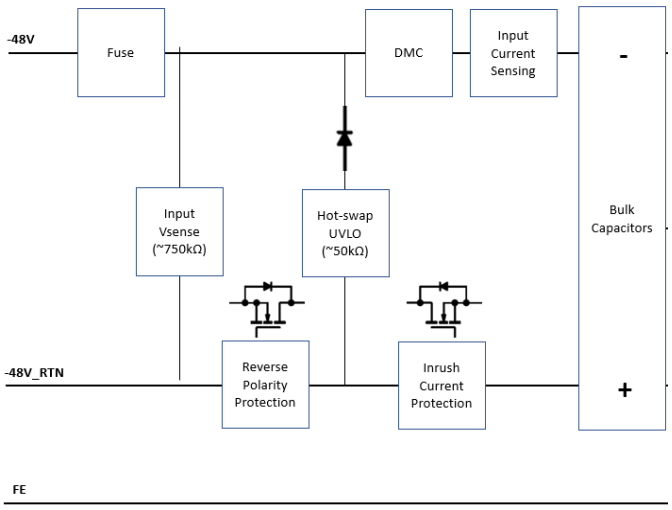


Fig. 2. Proposed System Block Diagram

At the front-end of the TLE rated 1.44kW (Output 1 loaded with 1.2kW and Output 2 loaded with 240W) placed are bidirectional TVS (TVS with voltage clamp of 80V) and back-to-back reverse current and inrush current protection FETs (FETs with low drain-to-source resistance and wide SOA connected in parallel to increase current handling capability). The reverse current protection FETs are being driven by the auxiliary circuit which gets its supply from the bulk capacitor. On the other hand, the inrush current protection FETs are being driven by a hot-swap IC which gets its supply from the input at normal operation and from the bulk capacitor during PDOT. The proposed system also has an input fuse for additional protection in case of internal short, differential mode choke (DMC) for EMI filtering and input voltage and current sensing resistors for voltage and current monitoring. Below is the working principle of the system at start-up & normal operation and during the UV & OV parts of PDOT.

A. Start-up & Normal Operation

At start-up, the bulk capacitor tends to charge until the voltage across it is equal to the supply voltage. This results to a huge amount of current known as inrush current which might damage the circuit components, and thus, must be limited to a safe level and duration.

To solve this, the inrush current protection FETs are designed to operate at linear mode during inrush event with the help of hot-swap IC LM5096. LM5096 senses the voltage and current across the inrush current protection FETs and maintain its power based on what was programmed to it to guarantee that FETs are always within SOA rating. Meanwhile, the reverse current protection FETs body diode momentarily handle the inrush current then eventually hands it over to the FETs once the auxiliary circuit turned on.

After the inrush event, both the inrush current and reverse current protection FETs remained on to handle the stead-state current.

B. UV Part of PDOT

During the UV part of the PDOT, the bulk capacitor sees a short on the input side which quickly depletes its charge and eventually causes the TLE to shut off.

To solve this, the reverse current protection FETs are designed to quickly turn off once a difference in source and drain voltage is detected. Since the whole circuit is disconnected to the input, the bulk capacitor is designed to have a hold-up time of > 1.5ms so the output will stay above the regulation until the input recovers.

C. OV Part of PDOT

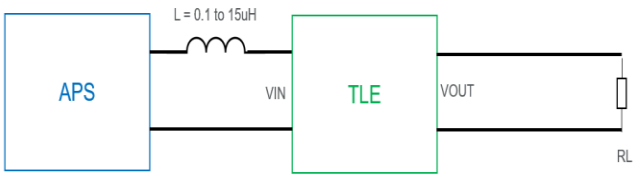
During the OV part of PDOT, the bulk capacitor tends to charge until the voltage across it is equal to the supply voltage. Same case at start-up, this again results to inrush current but since inrush current protection FETs are already fully on, this might trigger the OC function of the hot-swap controller causing inrush current protection FETs to turn off and eventually causes the TLE to shut off. Same scenario might occur if the OV protection function of the LM5069 is triggered.

To solve this, the LM5069 circuit breaker protection function is delayed by adding a capacitor across the current sense resistors which technically disables it while the OV protection function was disabled by shorting the OVLO pin to ground. TVS helps in clamping the OV part of the PDOT so the maximum input voltage supply of LM5069 it will not be exceeded.

With this approach, the TLE will remain operational and most importantly will not be damaged during and after PDOT.

III. TEST RESULT

To validate the performance of the proposed system, the electrical parameters of the TLE was monitored during start-up, normal operation and PDOT using the test set-up shown in Figure 3 (a) with input generated using APS10000 shown in Figure 3 (b).



(a)

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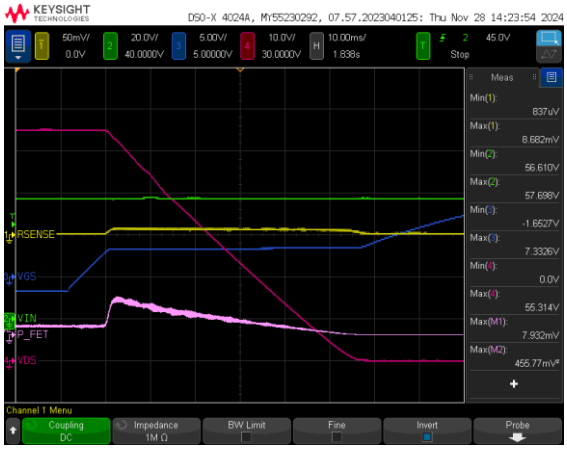
(b)

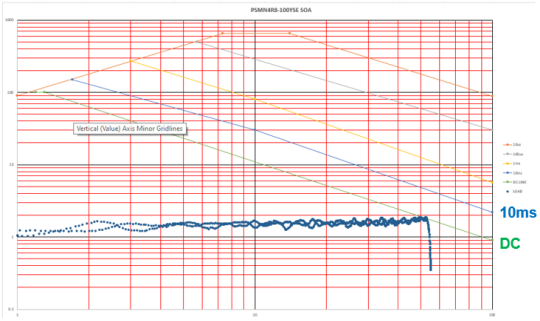
Fig. 3. (a) Test Set-up using (b) APS10000 Source

At start-up, inrush current protection FETs' current waveform and power dissipation are shown in Figure 4 (a) and (b), respectively. With a current sense resistor value of 0.75mΩ and voltage of 8.682mV, the inrush current is only 11.576A. Power dissipation is also within SOA.

After this inrush event or at normal operation, current is just a function of the load while power dissipation is just a function of current and FET's drain to source resistance.



(a)



(b)

Fig. 4. Inrush Current Protection FETs (a) Current Waveform and (b) Power Dissipation

For the UV part of PDOT, the output voltage waveforms are shown in Figure 5. Output voltages decay, stay within regulation (above -40V) and go back to normal level as soon as the input recovers. The 3.3VSB output of the auxiliary circuit also stays within regulation.

Fig. 5. Output Voltage Waveforms During UV Part of PDOT

For the OV part of PDOT, the output voltage waveforms and current waveform are shown in Figure 6 (a) and (b), respectively. Input voltage is clamped by TVS to 80V and so the output voltages shoot up to 80V only for 10ms and go back to normal level as soon as the input recovers. The 3.3VSB output of the auxiliary circuit also stays within regulation. For the current, a spike of 425A is measured which is still below the total current rating of parallel connected inrush current protection FETs and parallel connected reverse current protection FETs.

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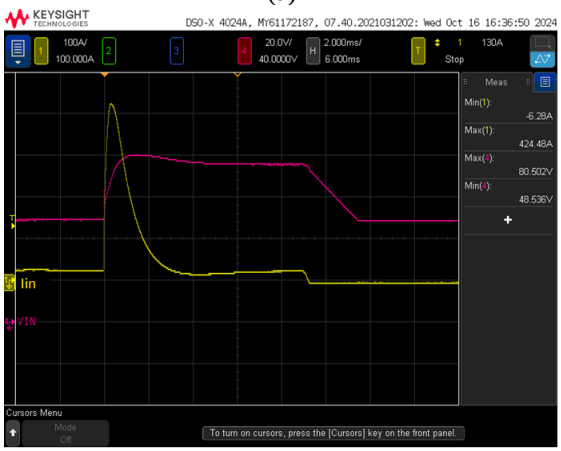
(a)



(b)

Fig. 6. (a) Output Voltage Waveforms and (b) Input Current Waveform During OV Part of PDOT

After PDOT, TLE was not damaged and returned to its normal operating condition.

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IV. CONCLUSION

A protection circuit against protective device activation transient was designed, developed and tested. By placing TVS and back-to-back reverse current and inrush current protection FETs at the front-end of the TLE with hot-swap IC OC and OV protection functions disabled, TLE was able to operate normally during and after PDOT, and thus, compliant to ATIS-0600315.2018 telecommunication standard. This supports the need for TLE that can operate in harsh environments guaranteeing safe and reliable operation eliminating downtime and its detrimental impact.

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