Designing and Building High Voltage Power Supplies

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***Abstract*— High voltage researches and testing is more lively than ever and a lot of activity is expanded on the World in a great number of high voltage laboratories. For present industry production to perform fast advances toward more reliable, longer life, cost-effective power supplies, a better understanding and application of tests for electrical performance, mechanical, thermal, and environmental tensions must be imposed by the statement of work and applicable specifications. This study shows the summary which outlines many requirements and specifications that are either unnoticed or taken for granted during the evaluation and production of high voltage power supplies (HVPS). The study contains the design summary, production and manufacture of prototype of the HVPS. Also high voltage guidelines to minimize failures were researched in the study.**

***Index Terms*—high voltage, power supply, designing.**

I. INTRODUCTION

There is an urgent need for long-life, affordable, highenergy density power supplies. Production technology, standardization programs, and workshops that have been implemented to emphasize the need for lighter weight, smaller volume, increment of reliability and, in many cases, lower cost. At first, many programs come forwarded to bring inventions toward higher reliability and longer life, only to find that life and reliability were good for the few power supplies delivered for the progress program. There are two reasons for the reliability and life releasing from its initial state. First, the initial orders were provided using special production techniques to build a few already designed power supplies. Second, the supplier did not include the required changes for the developed design in the production and test procedure because of cost and timing. Due to developments in design, production and test must be either specified at contract initiation or a new contract for following changed power supplies must be published [1].

Electrical design, packaging, materials and processes,production and test are equally important to the life, reliability, and cost effectiveness of a compact power supply. Until now,no single electrical or packaging design has all the ideal electrical, thermal, and structural properties for all applications; thus, the engineers must accept that each application has a set of designs both satisfy the electrical performance and meet the environmental and structural constraints. The designer must evaluate concessions when selecting the correct packaging techniques for electrical insulation and processing for a reliable, compact, lightweight,HVPS [2, 3].

II. HIGH VOLTAGE POWER SUPPLIES

A HVPS is a low voltage power supply with some special high voltage sub circuits and parts. This means that many circuits within a HVPS are similar the low voltage power supply. Similar circuits include the input filter, switcher, control and built-in test equipment (BITE) and automatic test equipment (ATE).

The special high voltage circuits include a high voltage transformer rectifier or voltage multiplier, high voltage filter, high voltage control sensors and output connector [1]. Series strings of diodes have been used for decades to rectify the output of high voltage transformers to obtain HVDC. More recently, other solid-state power semiconductors are being used in series in a variety of high voltage applications. For example, series-connected SCRs Silicon Controlled Rectifiers) are being used in crowbars [4] as a replacement for ignitrons. Series-connected IGBTs are in use as fast on–off high voltage switches [5, 6]. A HVPS is defined as any unit having voltage equal to or higher than 300 volts, peak. High voltages, including transients, are subject to corona breakdown and partial discharges. Partial discharges and corona can occur at low voltages. That is, as frequency increases, the corona initiation voltage occurs at low value. At 200 MHz, corona initiation can be as low as 50 volts peak. Therefore, effects of frequency must be considered in the design of all high voltage and low voltage switching power supplies. Corona and partial discharges initiate more failures in high voltage electrical insulation designs than any other cause. He designer must be aware of this fact and insist that the encapsulating materials are compatible with parts insulating circuit boards, and the metal structure

. *A. **Design Summary***

Although design of the HVPS is very important, it s usually done by electrical, electronic and mechanical engineers. Corona and partial discharge problems cannot be fully removed in all applications, but they can be kept to an acceptable level. An acceptable level is one where all large gaps that grow rapidly and break down insulation are eliminated. Very small discharges in micro gaps will destroy the insulation, but it may take years of continuous operation. The desired features of a HVPS are as follows: fast recovery time, extraordinary crowbar unit at the load end to avoid complications and minimize failure risk, minimal indoor/outdoor space requirements and high performance, high availability target [7].

An encapsulated high voltage circuit in a HVPS with comfortable coated low voltage circuits can be developed with small weight penalty. It will be easily cooled and the potted operating voltage plus 1000 volts for high voltage parts and circuits. That value is still used by the power industry for voltages where the stress levels will not damage the electrical insulation. For very high voltage, over 115 kV smaller maximum voltage stress values are used. Because high voltage power supplies are developed with high stress levels, the DWV test should not exceed two times the operating voltage. Corona starting voltages and extinction voltage are non-destructive tests that indicate the probability of gaps, cracks, and limitation in parts boards and wiring. Corona tests should be performed before temperature cycle and post temperature cycle. Changes in the size or quantity partial dischargesindicate gaps or insulation cracking at the surface of parts. Any increase in the partial discharge characteristic is cause to fail the test. Arc resistance and short-circuit tests should be mandatory high voltage tests. First, corona tests of the high voltage cable must be done and then the short circuit tests must be done. For some voltage multiplier designs, the arc resistance test can overstress the final capacitor in the circuit or the voltage divider circuit. Any defects in the insulation will be detected by the corona test.

Environmental tests for high voltage power upplies should be almost the same as for low voltage power supplies. The one basic difference is the high voltage circuits. Safety rules must be applied finely to provide no dangers to humans are encountered. For example, the high voltage circuits must be completely grounded and remain grounded along the shock and oscillation tests unless otherwise directed. Special feedthroughs, connections, and interconnects must be designed for operating. These designs must all be safety approved. EMI, radio frequency interference, and electromagnetic pulse may all require test and evaluation. These tests should be made in shield rooms using certified, qualified test evaluation equipment. The low voltage circuits as well as the high voltage circuits must pass all tests and requirements to be fully accepted [1, 9].

*C. **Production***

High voltage power supplies are bothered by pollutants, wreckages, incorrect installation procedures and processes, and testing. Cleaning, excellent inspection and test procedures, trained personnel and good test equipment and test procedures are very important to appropriate production with high-quality, highly reliable, long-life power supplies. Parts, subassemblies, wiring and the power supply must be controlled, installed and handled using clean room techniques. When the parts are received from the suppliers and inspected, they should be bagged or placed in clean receptacles for storage before distribution to the assemblers. All installation personnel should be instructed to wear white cotton, lint-free gloves or equivalent when combining the parts on the boards, and combine in the final installation. Those who assemble low voltage, charge-sensitive parts must be instructed to work at electrostatic discharge workstations.They too should wear white cotton, lint-free gloves. All incoming receiving high voltage parts should be subjected to 100% control. Parts should be checked and tested for specification compliance and to eliminate all early failures before they can be combined. This saves a lot of rework and early failures. Many solid-state devices, capacitors, transformers, and voltage dividers should have a required bum-in test. This will select most early failure parts. Many parts suppliers do their own bum-in tests. When a supplier does the burn-in test, the procedure, time and characteristics test values should accompany critical parts such as capacitors, transformers and solid-state devices [10]. Specified personnel to the high voltage installation area should be trained to do the special installation and solder techniques required for high

voltage installations. Job training may require coaching from engineering as well as shop instructors. Training by engineering is especially important for quality control, inspectors, and test personnel. The purpose is to motivate the installation personnel to do high-quality, efficient work. There are many ways to cover or pot a high voltage subassembly or installation. Most result in many failures and rejects. Two methods are used with excellent success: vacuum impregnation with overpressure cure, and vacuum injection molding with cure under pressure. The pressure cure keeps bubbles from forming during cure. Tests should be performed to ensure that the vacuum pressure times and cure temperature are optimum for the material.
Lack of cleaning control of workroom causes poor vacuum impregnation results in gaps and poor workmanship results in high field stresses, partial discharges and failures. The corona test is the best test technique to determine these failure mechanisms. Much has been said about inspection and test. Three things that show up as overstress are sharp-edged parts, boards, and subassemblies. They are difficult to find because they do not occur in all components. Tests bring out three failure modes found in high voltage subassembly and power supply production. They are cleaning, poor vacuum impregnation and workmanship [11].

III. HIGH VOLTAGE GUIDELINES TO MINIMIZE FAILURES

High voltage power supply production and design is greatly affected by cost, time, and workmanship. Some urgently designed and produced equipment, developed at low cost, may result in overstressed insulation. This section discusses major causes of overstress and failure during the design and manufacture process. This discussion is followed by regenerative guidelines to minimize the probability of overstress and unfortunate failures.

*A. **Technical Exchanges***

Technical exchanges in design should be held between the contractor and the power supply producers, production and test personnel. The purpose of these technical exchanges is to search for problem areas and find solutions that result in highly reliable, long-life power supplies. The most important guideline to follow is to estimate future failure modes and prevent them. For example, a whole new development program is in progress for high-density power supplies. Power supplies developed for airplanes before 1985 had relatively low efficiency and were overtired with thermal problems. When determining the power density of a power supply, all parts must be included. That is the input and output connectors, switchers, rectifiers, filters, controls, BITE and ATE, heat removal, and structure to fit into the mainframe. Dielectric parameters critical to high voltage design are temperature, material thickness, humidity, area, dielectric constant dissipation factor, degree of dielectrics between surfaces, component electrode configuration, and gaps. Unconformity of dielectrics within an insulation system is caused by placing the low dielectric constant material next to small radius conductor in a multiple dielectric system. The greatest impact is for gas-filled gaps next to a curled wire conductor. The ionized gas heats the dielectric, and causes gradual impairment of the solid material. The correlated physical parameters with components and the completed power supply that caused problems follow:
□□Similar materials for stressing in large component such as transformer coils, high voltage solid-state
power devices, transformer cores, and base plates.
□□Placing low voltage sensitive circuits in a high voltage compartment.
□□High voltage and low voltage wire separation.
□□Lack of corona shields around nuts, screws, sharpedged components and terminations.
□□Bonding of multi dielectric systems such as epoxies and silicones.

*B. **Stress Interactions***

Design stress interactions are reconciled with the electronic design, selection of materials and components, the packaging design, the design of the production fixtures, and the testing parameters. Production stresses can be caused by wrong mixing, potting, and curing of the materials, component and module installation, workmanship, and production facilities and environment.
The problems associated with installation and tests are caused by the production procedures developed by engineering, the production and installation of the components and equipment, and the in-process installation and acceptance tests. Areas of concern in packaging high voltage solid systems are given in Table I. Solid insulation has electrical, mechanical, thermal, and chemical properties. These and other various properties are detailed in Table II. Sometimes materials are specified to be

transparent so that the packaging engineer can assess parts stressing and bonding. Weight, water absorption, and out gassing are often specified. Most important for all categories of high voltage insulation is life, which depends on electrical stress and the environment [12].

Contamination by waxes, greases and oils aftercleaning.

Mounting parts on circuit boards with exceptionally small gaps, which prevents filling with the encapsulant.

Circuit board configuration. Potted, densely populated, long, wide circuit boards that crack at low temperature

IV. CONCLUSION

The guidelines of design and production are proposed for use by low voltage and HVPS designers, technicians, program managers, and production technologists. Because a designer has successfully developed an excellent power supply is insufficient for continued success. New, high-density, high efficiency power supplies must be developed with an entirely new set of problems and solutions. The purpose of the study is to give the industrial designer and manufacturer, engineering and technical personnel a better insight into problems and solutions for high voltage power supplies. Thus in this study, problems encountered in the design and prototype development of HVPS and solving of these problems have been focused on. It has been also examined technical changes can be made and the stress interactions was investigated. It is estimated that about several years would be required to deliver all the HVPS, which includes simulation studies, engineering design, making of first prototype.

REFERENCES

[1] W. G. Dunbar, “Design guide: designing and building high voltage power supplies,” Interim Report for Period 1988, Space Power Institute
231 Leach Science Center, Auburn University, 1988.

[2] X. Dapeng, W. Yan, L. Ping and L. Guofeng, “A Double Short Pulse High-Voltage Power Suply Based On DSP”, 2004, pp.381-384.

[3] J. Chunrong, D. Zhigang and Z. Jingxuan, “Design on High Voltage Power Supply of Fiber Current Transformer”, Energy Procedia, Vol. 14, 2012, pp. 376 – 381.

[4] R.L. Cassel, “A 95 kV klystron power supply crowbar using light triggered SCR, in JT-60U”, IEEE International Power Modulator Symposium and High Voltage Workshop, 2004, San Francisco,California.

[5] T. Fujii, M. Seki, S. Moriyama, M. Terakado, S. Shinozaki, S. Hiranai,et al., “Operational progress of the 110GHz-4MW ECRF heating system in JT-60U”, Third IAEA Technical Meeting on ECRH Physics and Technology in ITER, 2005, Como, Italy.

[6] J.F. Tooker, P. Huynh, R.W. Street, “Solid-state high voltage modulatorand its application to rf source high voltage power supplies”, Fusion Engineering and Design, Vol. 84, 2009, pp. 1857–1861.

[7] P.K. Sharma, F. Kazarian, P. Garibaldi, T. Gassman et al., “Proposed high voltage power supply for the ITER relevant lower hybrid current drive system”, Fusion Engineering and Design, Vol. 86, 2011, pp.819–822.

[8] A.J. Acero, C. Ferrera, J.M. Montanero, M.A. Herrada, J.M. López- Herrera, “Experimental analysis of the evolution of an electrified drop following high voltage switching”, European Journal of Mechanics B/Fluids, Vol. 38, 2013, pp.58–64

[9] A. Fernández, J.M. de la Fuente, D. Ganuza, et.al., “Performance of the
TJ-II ECRH system with the new −80 kV 50 A high voltage power
supply”, Fusion Engineering and Design, Vol. 84, 2009, pp.772–775.

[10] J.H. Jeong, Y.S. Bae, M. Joung, H.J. Kim, S.I. Park, “Development of high voltage power supply for the KSTAR 170 GHz ECH and CD system”, Fusion Engineering and Design, Vol. 88,(5), 2013, pp.380-387.

[11] H.J.M. Blennow, M.Å.S. Leijon, S.M. Gubanski, “Active high voltage insulation”, Journal of Electrostatics, Vol.55 (2),2002, pp.159- 172.

[12] T. Bonicelli, R. Claesen, A. Coletti, P.L. Mondino, M. Pretelli, M. Santinelli, L. Sita, G. Taddia, “ High frequency/ high voltage solid state body power supplies for CPD gyrotrons”, Fusion Engineering and Design, Volumes 66–68, September 2003, Pages 543-548.