DIGITAL EXCITATION SYSTEMS—
GROWING OBSOLESCENCE OF AGING SYSTEMS

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Richard C. Schaefer
Senior Member, IEEE
Basler Electric Company
12570 Route 143
Highland, IL 62249
USA

Abstract – The life expectancy of digital excitation systems is influenced by the availability of spare and replacement parts. Many factors affect the ability of manufacturers to continue producing these systems and providing replacement parts. Strategies exist for prolonging the life of existing digital equipment and minimizing the cost impact of complete replacement.

Index Terms — digital voltage regulators, operating software, analog voltage regulators, obsolescence, excitation limiters, hazardous materials

I. INTRODUCTION

When one thinks of aging excitation systems, one typically doesn't consider digital systems because the word "digital" implies modern technology. Digital excitation systems are very reliable and many have been in service since the early 1990s. But with any hardware, there is a life expectancy which is influenced by the availability of spare and replacement parts. The availability of direct-replacement components to correct a hardware failure may be questionable after about 15 years of service.

Many factors affect the ability of a manufacturer to continue to produce a product. These factors include:

- Materials identified as hazardous by regulatory agencies;
- Access to component parts and company buyouts;
- Obsolete technology such as computing hardware;
- Old operating systems (software, ASCII, DOS, or terminal);
- New feature enhancements; and
- Hardware efficiencies.

This paper explores these factors and discusses strategies for prolonging the life of existing digital equipment and minimizing the cost impact of complete replacement.

II. GENERATOR EXCITATION PRINCIPLES

The principles behind generator excitation have remained constant throughout history. To produce ac power, a generator requires the application of dc power to its field. This magnetizes the rotor which creates a flux within the generator air gap. Once this magnetic field is created, like a transformer, voltage is developed at the output of the generator. And, because of this magnetic field, mechanical power is converted to electrical power and transmitted to the outside world once the generator breaker is closed.

III. EVOLUTION OF EXCITATION SYSTEMS

A. Rheostat Control

Early excitation systems were manually controlled with a rheostat (Fig. 1). The operator had the sole responsibility of monitoring the generator voltage. If a voltage disturbance occurred, the operator was responsible for adjusting the voltage rheostat to restore the system voltage. Fig. 2 illustrates this scheme. These systems were later automated with the rheostat controlled by the output contacts of an electromechanical voltage regulator.

Fig. 1 1940's voltage adjust rheostat

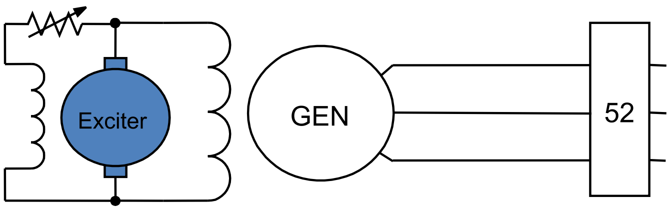

Fig. 2 Generator voltage control by rheostat

B. Analog Control

Sophistication and generator voltage performance improved with the availability of analog voltage regulators.

Amplidyne voltage regulators (Figs. 3[A] and 3[B]) were continuously-acting regulators providing a buck-boost bias via the automatic voltage regulator (AVR) rheostat. This technology exhibited much-improved response over previous methods.

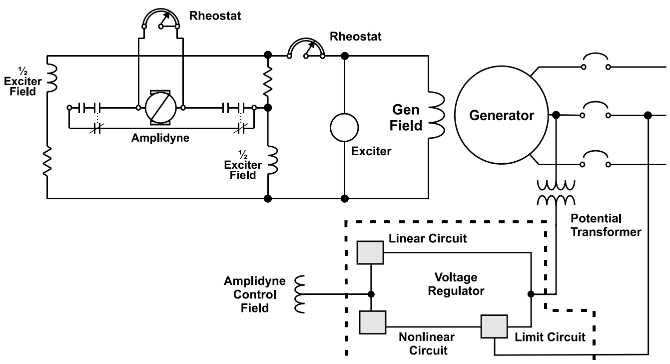

Fig. 3(A) Amplidyne schematic

Fig. 3(B) Amplidyne voltage regulator

In the 1960s, electronic analog voltage regulators became the preferred control solution and remained popular through the late 1980s. The many components of an analog excitation system are pictured in Fig. 4.

Fig. 4 1970's analog excitation system

Excitation requirements for supplying the exciter field of a synchronous machine can range from 1 Adc to as much as 200 Adc. For generators with only one field, the excitation requirements become much greater. Here, the main field requirements can range from 100 to 9,000 Adc at 63 to 375 Vdc. For these systems, analog controllers were supplied with a feature-rich set of controls to safeguard the synchronous machine from a variety of circumstances. These features included:

- Voltage regulator, field current regulator, field voltage regulator
- Volts per hertz limiting to prevent machine overfluxing
- Automatic tracking of manual control to the voltage regulator
- Maximum excitation limiting to prevent generator rotor overheating
- Minimum excitation limiting to prevent generator pole slip
- Power system stabilizer for system stability issues

C. Digital Control

The introduction of digital excitation control systems (Figs. 5[A] and 5[B]) in the late 1980s provided the means of combining a full complement of features into a single, compact product. Multiple features previously supplied by individual circuit boards and modules were now included in a single package that reduced the wiring requirements and complexity of an excitation cabinet. This technology also provided the ability to capture event data triggered by a system disturbance.

Since the introduction of digital excitation control systems, microprocessor technology has continued to evolve and provide the additional features and software tools that have become necessary to address the increasing expectations of changing market and regional agency requirements.

But what about older digital-technology equipment—is it still viable? And when it is not viable, what options exist?

Fig. 5(A) Digital excitation control system

Fig. 5(B) Digital excitation control system

IV. FACTORS AFFECTING OBSOLESCENCE

Multiple factors can bring about obsolescence of a digital product. These factors may include the availability of purchased materials, technology changes, and operating software that can be impacted by the availability of a computer type, model, or its operating software.

A. Resistors

Resistors are used in a majority of electronic products and the carbon composition resistor was the standard for many product designs. It has an excellent package to heat-dissipation ratio, requiring less space. Unfortunately, the material sources for these resistors are mines owned by warlords and reputable companies cannot tolerate the risks associated with conflict minerals [1].

Instead, metal film resistors are being used and their power dissipation is inferior to that of carbon composition resistors. The difference requires new circuit board layouts with increased spacing.

B. Capacitors

Electrolytic capacitors can pose a safety hazard as well as an environmental concern.

The manufacture of tantalum capacitors again can involve conflict minerals and their replacement requires an updated circuit board layout with increased electrical spacing.

C. RAM and Flash Memory

Memory technology changes rapidly and new innovations quickly supersede older solutions. A manufacturer may stop producing a component. Company buyouts occur and a specified component may fail requalification in determining if it still meets the original requirements for a product [2].

D. Modular Printed Circuit Boards

The modular design represents the inclusion of many specialized components that were pre-purchased that became obsolete while its replacement may require new operating software and PC hardware. In most cases the manufacturer's specification for an updated circuit board no longer meets the original design criteria. [3].

E. Computers

Computers serve as a necessary interface with a digital excitation system and complications can arise with aging hardware. Communication issues may occur when an older digital excitation system is connected to a newer computer with a much higher operating speed.

An older system may require a computer operating DOS, ASCII, or terminal emulation. Emulation programs are available but not all are compatible with newer computers.

Software used with older systems may use floppy disks (Fig. 6). How many of today's computers can accommodate these disks?

Fig. 6 Floppy disks

New computer operating software is not always backward compatible with existing system designs. So, for many existing excitation systems, the life of the equipment may be limited to the life of the computer being used to communicate with the system. Keeping the original operating software, and perhaps the original computer, is required to continue utilizing the original equipment. Some facilities may have issues with the Windows® XP operating system which is now obsolete.

Another potential concern is power supply voltages. In the quest for higher efficiency and lower heat dissipation, operating levels have migrated from a range of 10 to 15 Vdc to 5 Vdc and down to 2.5 Vdc. This can cause compatibility issues between new devices and old devices.

V. New Technology

Continuing microprocessor advancements have yielded additional performance features and testing tools to meet the modeling requirements and agency requirements of specific locales.

Multilingual software interfaces (Fig. 7) accommodate global users.

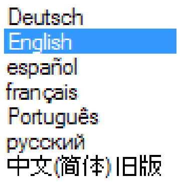

Fig. 7 Multilingual software

Auto-synchronizer functionality provides governor and voltage control during synchronization.

AVR auto tuning functionality, illustrated in Figs. 8(A) and 8(B), uses an algorithm to determine the gains needed for optimum generator voltage stability.

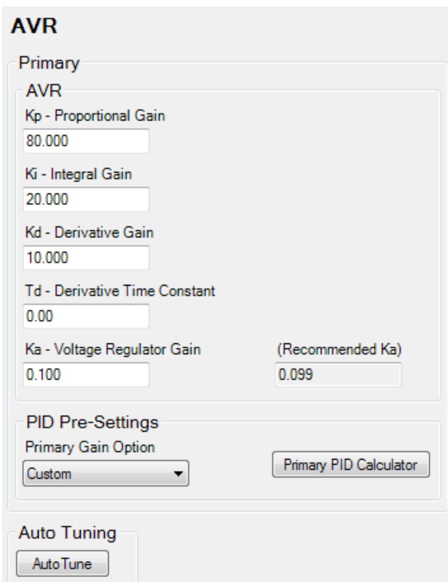

Fig. 8(A) AVR auto tuning gain settings

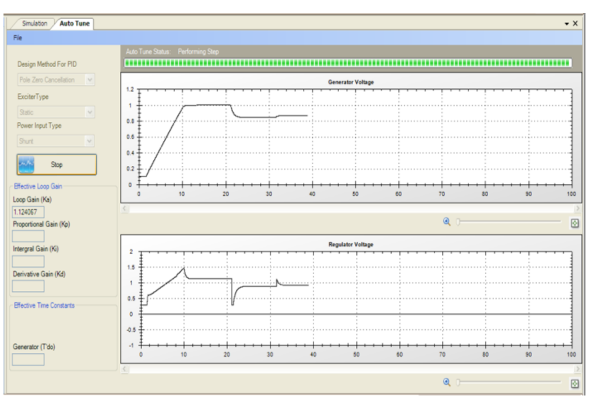

Fig. 8(B) AVR auto tuning function

Real-time monitoring is part of the operating software and eliminates the need for an external chart recorder during commissioning.

A dynamic system analyzer (Fig. 9) models the generator excitation system and is required for machines with a rating of 10 MVA or greater where regional agency requirements must be met to comply with regulatory standards such as NERC Standard MOD-026-1 in the US. The dynamic system analyzer enables generator and voltage regulator frequency response testing to determine the phase and gain of the generator excitation system. This information is used by transmission engineers to determine the behavior of the synchronous machine and excitation system during a system disturbance.

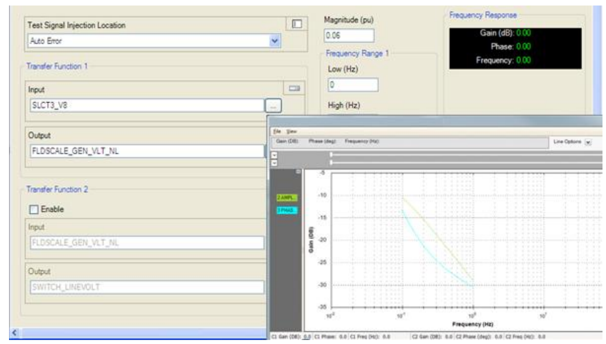

Fig. 9 Dynamic system analyzer

A test analysis function provides the means to perform generator step voltage response testing. This testing determines the generator voltage rise time that results from the selection of the voltage regulator gains, also a part of the requirement for regulatory standards such as NERC Standard MOD-026-1 in the US.

Storing sequence of events records (Fig. 10) in nonvolatile memory preserves these records when a loss of control power occurs. Having nonvolatile memory ensures that important data is never lost.

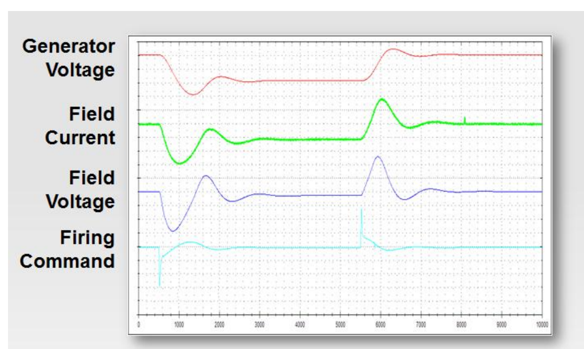

Fig. 10 Sequence of events record

Modeling simulation software is part of the operating program and can emulate the turbine, generator, and excitation system without operating the machine. Previously, an outside purchase would be required for this functionality.

Commissioning a generator excitation system requires the monitoring of machine behavior and entry of excitation system settings through several operating software screens. Today's operating software enables creation of a set of "favorite" screens (Fig. 11) which appear each time the software is initiated and make the commissioning process more efficient.

Fig. 11 Simulation software with multiple-screen monitoring

VI. Deferring Obsolescence

A. Manufacturer Strategies

A manufacturer can employ several strategies to extend the life of their equipment and avoid requiring a customer to replace an entire excitation system. These strategies include:

- During the design stage, components can be sourced from manufacturers that serve major, long-surviving industries such as the automotive industry
- For high-volume products, a redesign of a particular component occurs often. Here, the replacement part is designed to provide a solution for an obsolete device that is no longer available.
- Purchasing a large volume of parts nearing obsolescence so that manufacturing of a device can continue. Depending upon part demand, this strategy can extend device availability for an additional two or three years.

B. Retrofit Solutions

Once a product can no longer be produced, a manufacturer can offer various solutions to minimize the cost of product replacement.

Form, Fit, and Function: A manufacturer may design a new product so that it will fit in the same space as the product it is intended to replace. This solution may be achieved with the design of an adaptor bracket or plate. Examples of these types of retrofit options are shown in Figs. 12(A) and 12(B). For some systems, the settings file will be directly transferrable so that minimum tuning is required because the same algorithm is utilized.

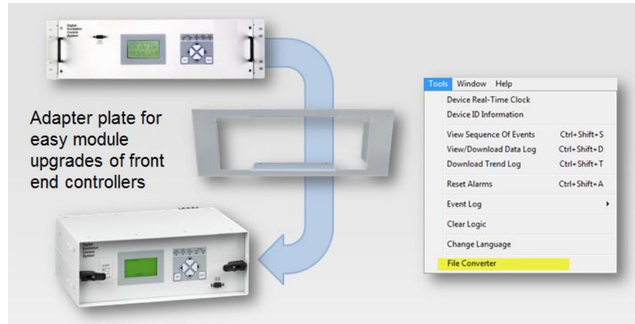

Fig. 12(A) Adaptor bracket

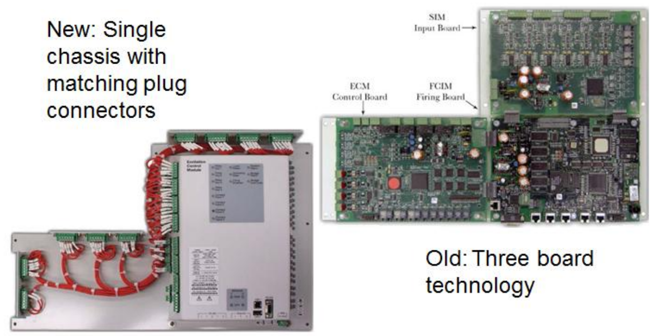

Fig. 12(B) Adaptor plate

Retention of Major Components: The life expectancy of the power potential transformer (PPT) used to power an excitation system often exceeds 30 years. Oftentimes, a significant cost reduction can be realized by retaining the PPT and replacing only the excitation equipment enclosure, see Fig. 13. This solution may not be possible in cases where special regional agency requirements mandate a new performance expectation that affects the design of the PPT.

Fig. 13 Complete static exciter cabinet less the PPT

Another common strategy is to retain major components in excellent condition such as the power bridges and circuit breakers. Here, only the voltage regulator controls and SCR firing circuitry for the power bridges are replaced. Fig. 14 illustrates the placement of new control electronics alongside existing power bridges.

Fig. 14 New control electronics with existing power bridges

VII. CONCLUSION

The life cycle of digital excitation systems is approximately 15 years and obsolescence of excitation system equipment can come about for a variety of reasons. This paper has discussed the factors causing equipment obsolescence and explored strategies used by manufacturers to extend the service life of these systems.

VIII. REFERENCES

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IX. AUTHORS' INFORMATION

Richard C. Schaefer, a Senior IEEE Member for 16 years, holds an AS degree in Engineering Technology. He is Senior Application Specialist in Excitation Systems for Basler Electric Company. Since 1975, Rich has been responsible for excitation product development, product application, and the commissioning of many plants. He has authored technical papers for numerous conferences including IEEE Power Engineering Society, IEEE IAS Pulp and Paper, EPRI, and IEEE Transactions on Energy Conversion and IEEE Transactions on Industry Applications publications. He has been involved with power plants for longer than 35 years.