IKE: AN INTERACTIVE KLYSTRON EVALUATION PROGRAM FOR SLAC LINEAR COLLIDER KLYSTRON PERFORMANCE*

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1. Introduction

SLAC probably has accumulated more high power klystron operating hours in the delivery of beams for physics research than any other laboratory in the world. Operating data has been logged by hand, and search of this data for klystron performance statistics is time consuming. When the new 65 MW klystrons for the SLC were planned, a computer based interlock and data recording system was implemented in the general electronics upgrade. Significant klystron operating parameters are interlocked and displayed in the SLC central control room through the VAX control computer. A program titled "IKE" has been written to record klystron operating data each day, store the data in a database, and provide various sorted operating and statistical information to klystron engineers, and maintenance personnel in the form of terminal listings, bar graphs, and special printed reports. This paper gives an overview of the IKE system, describes its use as a klystron maintenance tool, and explains why its valuable to klystron engineers.

2. System Requirements

To be an effective tool, the IKE system requires a database, a graphics system, fast response time, and currently 20 megabytes of disk space. The SLC control system VAX computer was originally thought to be the most desirable location for IKE to reside because on-line operators could diagnose klystron problems by examining the history of their performance. But considering the current load on this system, IKE was implemented instead on the IBM 3081 mainframe which has a powerful database management system, SPIRES,[1] a graphics system, TOP DRAWER,[2] a command language, REXX, to interface between the subsystems (SPIRES, TOP DRAWER and the user interface), and the required system resources. The data acquisition software runs on the VAX but its impact is negligible.

3. Data Acquisition

To acquire klystron operating data, a program, written in VAX FORTRAN, runs on the SLC Control System VAX. It issues data requests that are sent to the klystron contr;ol and monitoring hardware[3] through a wide-band cable network.[4] The klystron data is processed, looking for incorrectly calibrated, disconnected, or bad hardware. These data and diagnostic files are sent to the IBM over an Ethernet network.[5] This process is schematically shown in Fig. 1.

The data is then loaded in the database management system (DBMS) which gives multiple users the ability to selectively search and sort the data. Table 1 shows a list of the klystron operating parameters stored in the DBMS.

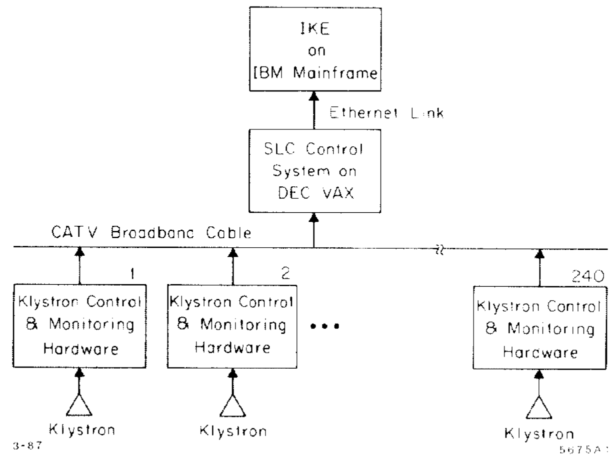

Fig. 1. Data Acquisition Network

Table 1. Klystron Parameters Stored in Database

• date	• tube number
• sector/station number	• klystron type
• beam voltage	• beam current
• micro perveance	• repetition rate
• body Δ temperature	• klystron vacuum
• waveguide vacuum	• window temp (right & left)
• high voltage running time	• focus current
• number of pulses	• fault, forward energy
• fault, reflected energy	• fault, over-current
• fault, over-voltage	• fault, vacuum
• forward power	• reflected power
• energy gain	• filament power
• amplitude jitter	• phase jitter
• RF drive power	

4. Display Functions

The database grows quickly when collecting thirty parameters, everyday, for each of the 250 on-line klystrons. It was necessary to produce a few standard daily reports, and also to give the advanced user the ability to search the database, define the format of the report and provide the ability to plot any parameter versus any parameter in bargraph form. The plots also contain a reference line indicating the nominal value for the plotted parameter for the particular klystron being studied.

When a user calls up the IKE program, they have a choice of selecting any of the standard reports or creating their own display by navigating through a series of menus which describe the search criteria. To search the database, the user defines his goals by putting upper and/or lower bounds on the operating parameters. For example, if a user wants to analyze klystron

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vacuum he may want to search the database looking for pressures greater than 1.0E-7 Torr with a daily vacuum fault count greater than 10 for all data taken this year. The actual result from this search is shown in Table 2.

Table 2: Formatted search result

Klystron Number	Date	Klystron Vacuum	Vacuum Faults
170A	01/07/87	1.3E–08	21
175A	01/25/87	9.29E–08	56
180B	01/25/87	1.5E–07	11
217A	01/06/87	1.2E–08	72
217A	01/07/87	4.8E–08	30
233A	01/25/87	1.19E–07	24
233A	01/26/87	7.4E–08	40
235A	01/21/87	1.3E–08	33
256A	01/28/87	3.09E–08	38
256A	01/30/87	3.19E–08	11
256A	02/14/87	2.99E–08	117
311A	01/02/87	9.19E–08	80
311A	01/05/87	2.99E–08	62
311A	01/08/87	7.19E–08	202
311A	01/12/87	1.39E–07	43
311A	01/13/87	1.19E–07	68
311A	02/06/87	1.39E–07	494
317B	01/13/87	5.7E–08	47
333A	02/21/87	7.8E–08	57

After examining this result, the user would probably want further information on klystron 311A. The user can plot the history of the vacuum and fault counts on the same plot and display this on his graphics terminal (see Fig. 2). Each bar on the plot represents one day of data. The horizontal line on the klystron vacuum graph represents the value of the vacuum when the klystron was manufactured. Gaps in the data show days when the klystron was off.

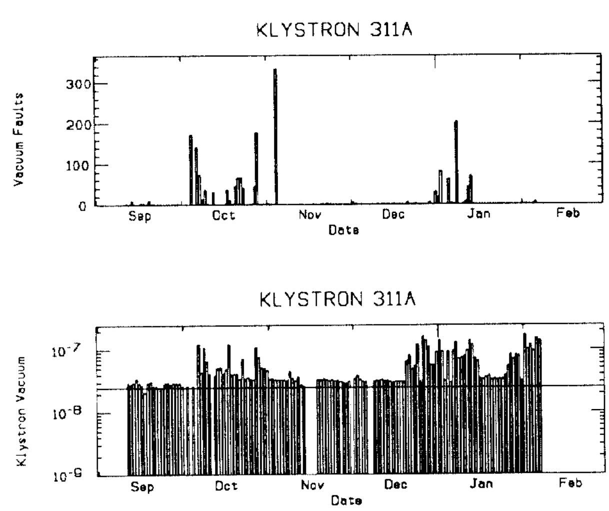

Fig. 2. Bargraph Display

5. Klystron Maintenance

Some "out-of-specification" klystron station operating parameters are interlocked to shut down the klystron. In these cases, the operators in the SLC control room are immediately aware that the acceleration function of that station has been lost. In most cases, however, a parameter drifts outside a nominal value to a point that the station performance is degraded, or the klystron may be in danger of being damaged. The on-line VAX analysis system picks up out-of-spec operation and flags the data displays, but unless the problem is acute, no maintenance response is immediately called for. Each morning, IKE generates a maintenance report that is called up by the klystron maintenance personnel. The present format displays all klystrons that have moved outside of the normal limits of beam voltage, beam perveance, or vacuum within the last 24 hours. Maintenance personnel then further inspects these stations to see if fault conditions are occurring.

Signatures of imminent failures are starting to be recognized with the short existence of the IKE system. For example, a rising beam voltage coupled with a dropping perveance indicates a klystron cathode malfunctioning, either from some form of poisoning, or from a drop in filament power. Also, parameter drift can be detected and analyzed such as decreasing focus magnet current or beam voltage.

IKE was also useful in the energy upgrade effort for SLC. It identified low power klystrons and helped resolve their operational shortcomings.

6. Klystron Engineering

IKE is an important tool for the klystron engineer because it allows easy access to the history of any klystron's performance. This information is important for operational and klystron life–time analysis as well as analysis of klystrons taken off–line for various fault conditions. It is expected that the klystron history data will give insight into how the fault condition developed, and what corrective actions are necessary to improve the klystron for on–line use. We have already had some success with this methodology. For example, a vacuum failure might result from a gassy cathode or a punctured high voltage ceramic bushing. The former is usually recognized by high vacuum readings while the latter shows a sudden jump in vacuum. Klystron 311A was taken off–line because of excessive faulting due to poor vacuum. From IKE (Fig. 2), it was learned that the klystron vacuum degraded to a value near the fault trip level (2.0E-7 Torr) and that small fluctuations in the vacuum caused excessive faulting. Testing of this klystron showed a gassy cathode but generally good performance, i.e. high power output and stable perveance (Fig. 3).

An example of a possible high voltage ceramic bushing puncture is shown in Fig. 4. The klystron was operating normally with stable high output power and good vacuum when suddenly the vacuum pressure jumped nearly two orders of magnitude and subsequently faulted and cycled off. The klystron was turned back on and is now operating under close observation.

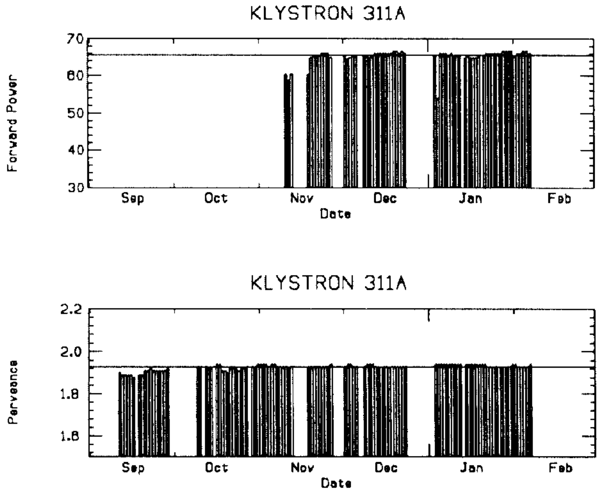

Fig 3: Power output and perveance

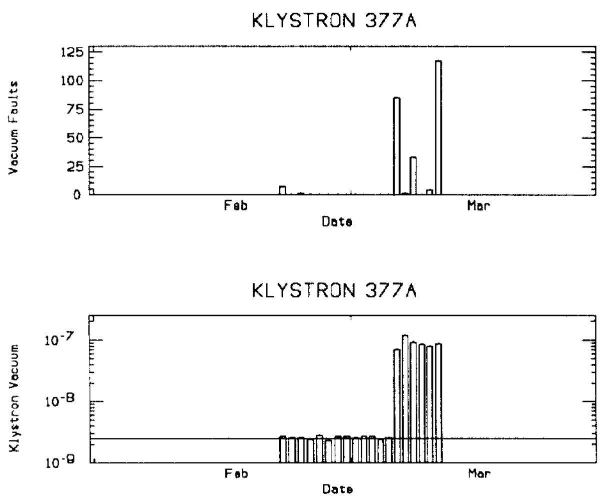

Fig 4: Sudden vacuum pressure increase

As soon as the instrumentation is complete, IKE will monitor the cathode emission properties of every on-line klystron to study life–time characteristics. In essence, this amounts to life–testing over 200 cathodes at various filament power levels. This should permit us to accurately predict cathode lifetime and therefore plan our future cathode requirements.

We are studying failure modes and trends with IKE to determine how klystrons fail and age. With this information we will design algorithms to analyse the daily operating data to detect incipient failure modes before the condition leads to klystron destruction. These algorithms will detect parameter drift from day to day or from the individual klystron manufacturing specification. They will also consider the effects from other parameters which could justify the change. For example, if a klystron's body temperature rises quickly but its repetition rate was also increased, then we know there is no need to be alarmed.

7. Summary

It has been shown how valuable IKE is to klystron maintenance personnel as well as klystron engineers. Not all of the hardware instrumentation is in place or calibrated, but it was deemed important to start logging what data was available as soon as the program was functional. We now have about six months accumulation of klystron operating parameters in a database which can be accessed and selectively inspected from any site computer terminal. Within the next year, there are plans to finish and calibrate the instrumentation hardware, and to further refine and broaden the analysis capabilities of the IKE program.

Acknowledgements

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