# EXPERT SYSTEM FOR DIAGNOSIS OF KLYSTRON MODULATOR(KMTS)

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## Abstract

A diagnostic expert system, KMTS (Klystron Modulator Trouble Shooting system), was developed for the Photon Factory 2.5GeV electron/positron linac and was connected to the linac computer network for receiving real data from the linac.

The klystron RF modulator is a 84MW pulse(4.5us) power supply operated at 25pps. There are 47 modulators along the 500m linac.

This project has been undertaken in an attempt to reduce linac operator's diagnosis duties and to explore AI technologies.

## Introduction

The Photon Factory(PF) Linac[1-3] is operated 24 hours a day, a total of 5000 hours a year, making injections to the PF storage ring and the TRISTAN e+/e- collider.

When any trouble occur in the Klystron Modulator, although the operator is usually not an expert to diagnose modulator trouble, he is required to do it, even at night.

Any assistance given to the linac operator regarding operation and diagnosis is extremely desirable. A knowledge-based expert system(ES) seems to be appropriate in order to optimize the operation environment.

We have been looking for appropriate expert system shells and tools with which to build up an expert system easily and rapidly.

For several years, a small ES based on a personal computer was initiated to be used for exploring the applications of AI techniques to the accelerator field. A prototype system, KMTS, had been build on a workstation by May 1989, and connected to the computer network of the PF Linac.

In KMTS, knowledge representation was very interesting; it was tried in order to determine whether or not the problems can generally be solved using an ES. The KMTS started to run, using hundreds of rules, for diagnosis from October 1989.

## Basic Approach

At present, each klystron modulator has several microprocessor units(MPUs) which are connected to the local network(LOOP-2) using optical fiber.

The LOOP-2 has a HDLC-like protocol developed in the PF Linac. When a fault occurs in a klystron modulator, the MPU picks up the first reason, FCS(First Change Status), for the trip down and sends a message to the minicomputer, MELCOM 70, in the subcontrol room through LOOP-3, LOOP-2, and CAMAC. There are 50 interlocks and analog data displays at the local klystron modulator panel. Of course, ES requires more information for complete diagnosis. Most of the same data which is available to check locally is transfered to the main computer and to the expert system.

The KMTS is triggered to start diagnosis upon receiving an FCS message through the network.

## Hardware Configuration

Figure 1 illustrates the hardware configuration of the KMTS and the network of klystron modulators. The KMTS has the following configuration: HP9000/370 ( development station), 375(linac operator's console), HP-UX, C, NEXPERT-OBJECT (HYBRID-tool), Data-View (graphic tool), equipped with a 16MB RAM, 300MB(600MB) hard disk, and 3.5 floppy disks. There is a pre-process station (FMR-50 personal computer) which has a 600MB magnetic compact disk (CD).

The KMTS involves a human interface for interviewing in multiwindows. The interface supports graphic multiwindows and a mouse. The KMTS is connected to the Linac computer network through the ethernet and RS232C.
Though there is important waveform information concerning various analog signals, these have not yet been taken into the KMTS.

## Fault rate

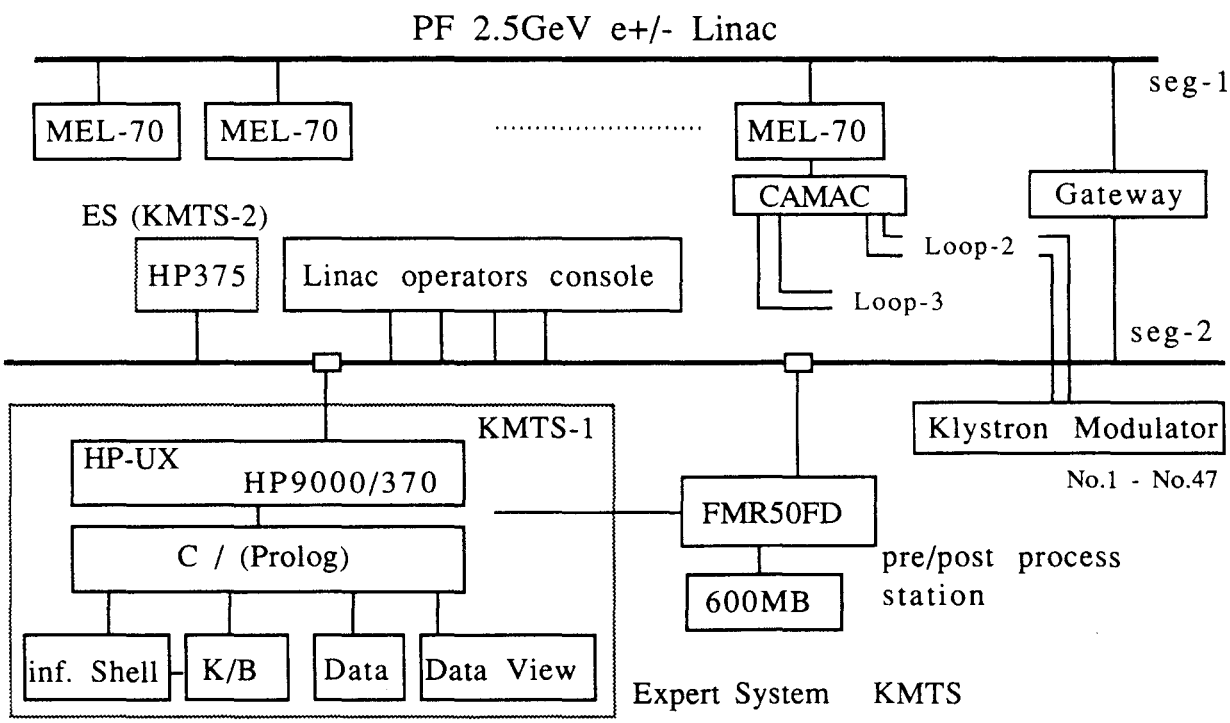
Under usual operation, the fault rate of the klystron modulators is 720 times/month.

In some fault cases, the modulator can not be recovered immediately without treatment by the operator.

Since the system receives real-time data concerning shutdown informations from the klystron modulator, it can usually be restarted very soon. This used to be done at the linac operator's discretion.

## Software configurations

The KMTS expert system has a debugging mode for diagnosis which makes it easy for users to carry out simulation at any time. The KMTS can operate in two modes (AUTO or MANUAL) at the operator's discretion. In the AUTO mode, when the KMTS receives serial shutdown data from pre/post processor through the network, it automatically starts diagnosis periodically. In the debugging mode, inference is fired manually by the knowledge engineer.
Each rule should be simulated in this MANUAL mode both before and after running using empirical knowledge.
Knowledge or result integration is carry out by C language.



## Knowledge Acquisition

Generally, knowledge acquisition can not be based on any model in this kind of diagnosis; KE(Knowledge Engineers) must build knowledge-base extracting rules and procedures in an empirical approach through interviewing experienced field experts regarding both operation and repairing.

One of the methods is to stimulate an expert who remembers by asking what operations and diagnosis must be carried out when facing troubles. Two months have been spent on interviewing and knowledge engineering during the first stage. After that, we determined that diagnosis concerning the klystron modulator would result in shallow targeted diagnostics, still a big help to linac operators.

It is also necessary to have other methods to obtain more knowledge by making sure after the system(KMTS) done.
A hundred expressions concerning production rule, frame, and object were handled by KE in the KMTS.

## Results

The expert system environment was constructed using easy user interfaces and a knowledge base concerning a shallow target.
Though the diagnostic capability is still primitive and limited, it is necessary to start with a small knowledge base in an expert system. Though the execution time of the expert system does not need to be very short, it is sufficiently fast and hundreds of times faster than human(operators) diagnosis. Therefore, the speed is not of primary importance at this stage.

Just after completing the expert system, the fault rate of klystron modulator became very low; consequently, we have started to change our goal to not only diagnosis, but also to offer an operation support expert system without big changes. The New K/B(Knowledge Base) including pictures and graphics are now being added and tested for expected phenomena in order to obtain more reliability. Moreover, we are studying CASE-BASED REASONING as well as how to gain transparency of the K/B. We are going to change the KMTS in order to be able to control the klystron modulator to turn it on by the KMTS. At the same time, an attempt is being made to construct an operation support expert system for the electron gun system of the linac. The new system will be different from the previous system.

## References

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