SCHEME OF MICROWAVE SWITCH BASED ARCING DIAGNOSTIC SYSTEM FOR 20 MEV PRE-INJECTOR MICROTRON OF INDUS COMPLEX

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Abstract

A microwave switch based control system is developed for diagnosis of arcing in 20 MeV microtron for Indus accelerator complex. The cause of arcing in microtron can be confirmed among microtron side and waveguide side using this microwave switch. The operator can adjust the microtron parameters accordingly to troubleshoot the arcing. The system is under implementation phase to upgrade the microwave waveguide system of 20 MeV microtron.

INTRODUCTION

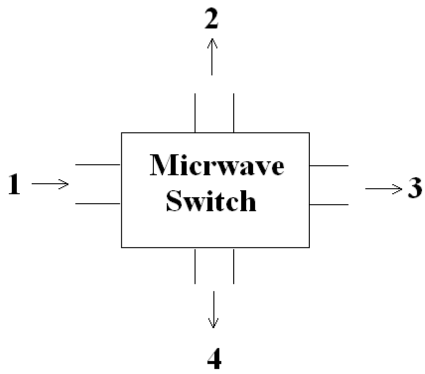
The energy breakdown process in a particle accelerator system is complex and critical. Its proper understating is indispensable for successful operation of machine. Breakdown can be defined as the energy discharge through occupying medium between two points or electrodes when energy level or potential difference exceeds the breakdown strength of that medium. At Raja Ramanna Centre for Advanced Technology (RRCAT)-Indore, Indus accelerator complex houses Indus-I and II, which are the synchrotron radiation sources having nominal electron energy 450 MeV and 2.5 GeV respectively. A 20 MeV microtron is used as pre-injector for booster synchrotron (700 MeV) and Indus-I (450 MeV).

Breakdown in 20 MeV microtron system causes undesirable effects such as distortion in forward microwave power pulse or beam shape. Among others, the sources of breakdown during machine operation could be low gas pressure in waveguide line or improper settings of microtron operational parameters. Arcing is special condition of breakdown discharge which is most damaging. This may occur after the glow discharge. While occasional arcing may reduce the efficiency of system and sub-system of microtron in long run, its diagnosis and remedy become essential for reliable operation of machine.

In microtron, a microwave accelerating cavity operating in TM_{010} mode at frequency around 2856 MHz accelerates electrons with orbits having common tangent at its accelerating axis. It is simple cylindrical pill-box cavity made of oxygen free high conductivity copper (OFHC). The coupling factor of microtron cavity is kept 2.62 (over coupled) which should be close to unity (critically coupled) during beam operation Microwave waveguide is connected to the cavity by aperture on the common wall. The dimensions of the slot decide the coupling of waveguide and cavity [1]. Diameter of the cavity decides the resonant frequency of the cavity. The voltage gradient (electric field) inside the cavity is about 490 kV/cm. The discharge owing to multipacting breakdown may occur in cavity whenever the electron’s mean free path length exceeds the cavity gap through which electrons pass. This discharge occurs when electrons move back and forth across gap in synchronism with microwave field. Such breakdown occurs below Kilpatrick level [2]. The present paper explains breakdown in microtron system and its diagnosis by microwave switch.

SYSTEM DETAILS

The microwave waveguide system of 20 MeV microtron consist of waveguide WR (waveguide rectangular)-284 line, 5 MW peak power klystron amplifier having WR-284 waveguide port as output port, E-plane bends, straight waveguide sections, alumina ceramic window, isolator and directional coupler. The isolator is used to protect the klystron tube from excessive reflected microwave power. This isolator protects the tube output window and can impede or even stop a travelling arc. While the isolator is effective in protecting the klystron tube, it will not prevent arcing in the remainder of the microwave system. Internal breakdown causes damage to the waveguide in an action that is often self-sustaining till the waveguide is damaged beyond use.



Ports:
1: Microwave power from waveguide,
2: Microwave power to dummy load,
3: No load
4: Microwave power to microtron load (cavity)

Switch positions:
Port 1-2: Power to dummy load (arcing diagnostic mode)
Port 1-4: Power to microtron cavity (normal mode)

Figure 1: Switching position details of microwave switch

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The schemed waveguide microwave switch (Fig. 1) is E-plane bend type which affects electric field lines of electromagnetic wave propagating down the waveguide. During normal mode, port 1 of switch should be connected to port 4 such that microwave power is delivered to microtron cavity. During arcing diagnostic mode, port 1 of switch should be connected to port 2 such that microwave power is delivered to dummy load. The maximum switching time of this switch is 200 ms. The switch has the motor requiring 1Ø, 230 V AC $\pm$ 10 %. [3]. The status of switch positions comes over the switching control system (driver mechanism) having light emitting diodes (LED) indicators. This control mechanism to drive the motor in two styles viz. ‘dummy load’ or ‘real load’ is designed and developed. The metal oxide variable resistors (MOV) are used in shunt mode to protect the motor against voltage spike. The 5 V DC supply is developed to conduct the status-LED over the control system.

CHARACTERIZATION DETAILS

The microwave switch is characterized in laboratory during cold–test by vector network analyzer which shows acceptable insertion loss viz. less than 0.1 dB at 2856 MHz frequency in all switching positions (Fig. 2).

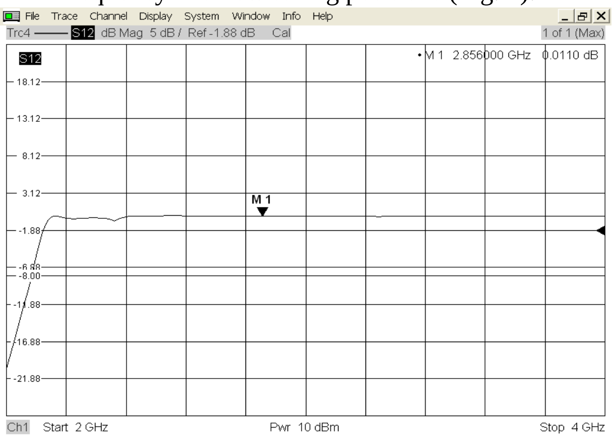

Figure 2 (a): Insertion loss for port 1 to 2

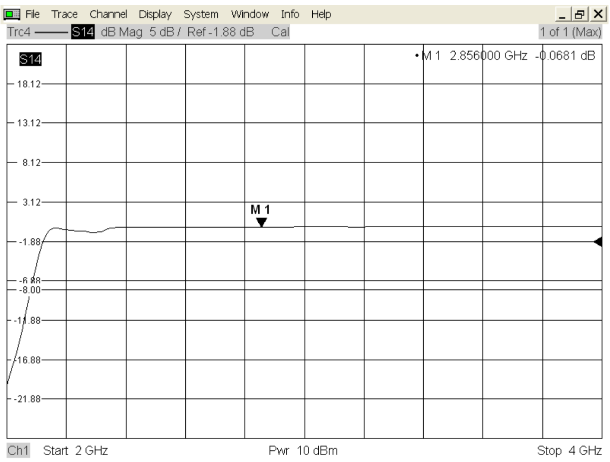

Figure 2 (b): Insertion loss for port 1 to 4

Figure 2: Switch characterization results

USAGE DETAILS

The diagnosis of microwave breakdown in 20 MeV microtron requires location and cause to find out. The microwave waveguide switch can serve this purpose. The microwave switch is to be installed at the place of E-plane bend near microtron along with dummy load at port 2 of switch. During breakdown in the entire system, forward microwave power pulse, monitored over oscilloscope appears distorted.

In order to check the breakdown in waveguide system during operation, the switch should be driven for dummy load such that pulsed microwave power coming from klystron is absorbed in dummy load. If breakdown is occurring in waveguide system then it can be minimized by reducing the microwave power till stable state is reached with no breakdown. After some time the microwave power should be gradually enhanced until operational value is reached with continuously monitoring the forward power pulse. If breakdown persists then operator needs to check the waveguide gas pressure and klystron settings.

When entire microwave system is healthy then microwave power should be driven towards microtron cavity in consultation with system expert. If breakdown is occurring in microtron side then cathode current should be minimized. When steady state with no breakdown condition is reached then cathode current should be increased gradually up to normal operational value. This can resolve the breakdown problem in microtron system.

CONCLUSION

A WR-284 waveguide microwave switch based system is designed and developed to diagnose the arcing during operation of 20 MeV microtron of Indus accelerator complex. By this mechanism, system operator can easily troubleshot the cause of arcing and take remedial steps. The system is ready for installation.

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REFERENCES

[1] Yuri M. Tsipenyuk, “The Microtron: development and applications”, vol. 10

[2] A.S. Gilmour, Jr, “*Microwave tubes*” Artech house, Inc., 1986

[3] Datasheet “MW284BPMLX68 Logus Microwave”