Functioning of High-Power Klystrons

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Abstract: A strong RF architecture for the particle accelerating agents requires huge electrical power in the activity. Improvement of productivity is furthermore continuously needed as an innovation component for the conserving energy. To enhance effectiveness of a strong RF source, the Collector Potential Depression(CPD) technique as of now was used a Gyrotron for recuperation of the electrical vitality structure the dispersed power in the collecting circuit. The CPD is an energy saving structure that recoups the active vitality of the wasted electrons subsequent to generating RF control. Above method offers higher exactness when compared with cell ID strategy. Cell ID is having precision equal to sweep of cell. In suggested method precision is about 30 metre. These methods don't need any equipment modification in portable handset. This method reduces the effect of multipath motioning on timing delay in metropolitan area by taking the normal of sign quality. At that point by taking the normal of n tests a better exactness may be achieved.

Keywords: CPD, Electronic Efficiency, Frequency, MOGA, Klystrons.

1. INTRODUCTION

The klystron is a very significant source of radio frequency energy, particularly in the fields of innovation, equipment, and structural material research. When it comes to structure, growth, and operation, there are a few key factors that need a great deal of practise. These include equilibrium, frequency, production strength, and performance. The electronic efficiency of the vast majority of high-control RF klystrons is anywhere between 40 and 55 percent, depending on the application. Only a few klystrons can transmit a maximum of about 65 percent of the total energy. The high proficiency of klystron structure and enhancement is becoming more important as prospective accelerating agents become more interested in it, and it has been recorded as a major invention in a number of different foundations. At IHEP, you may find a simplified and comprehensive arrangement of high-competence klystron structure and klystron structure development. In order to increase the efficiency of the klystron, the spatial and stage profile of the package should be such that each electron has indistinguishable speed after deceleration by the exit hole, which is unimaginable due to the behaviour of room charge strength, and each electron has indistinguishable speed after deceleration by the exit hole [1].

It is common practise to utilise the klystron beam purveyance as a measure of the proportion of room charge forces: the lower the purveyance, the more delicate the space charge and the more grounded the batching. High-profile klystrons, for example, need a low purveyance in this way. It has been discovered that the "Core Oscillation Method" (COM) grouping alignment spectrum utilising the depression of third symphonies and multi-beam klystron may be used to significantly improve klystron capabilities. For a long time, the construction of klystrons was accomplished only via human labour and accumulated expertise. With the study of grouping components and the programming of recreation programmes, a reasonable approach for klystron structure is now available, as is a sufficiently fast reproduction methodology. Typically, 1D replication equipment is employed in the klystron structure to identify the high productivity scenario, and then 2D or 3D programming is used to examine and show the complicated effects. A particularly laborious and expensive issue for the high productivity klystron structure is science recreation based on computer programmes, which is the first portion of the klystron structure and serves as the foundation for the rest of the structure [2].

The following are the parameters of a seven klystron depression: six float tubes; seven frequencies; Qe input; and some Q factor, totalling about fifteen parameters. Improving the structure of all parameters is required in order to achieve maximum efficiency; this calls for a massive increase in measuring capacity. Genetic formulae were given in this article, which were created using the 1D leisure programme AJDISK. In the klystron construction, the utility as well as the overall length are taken into consideration. As a result, the term "Multi-Objective Genetic Algorithm" (MOGA) was introduced in this paper. A high priority problem is the improvement of the efficiency of RF power production for future big accelerators such as the Compact Linear Collider (CLIC), International Linear Collider (ILC), European Spallation Source, Future Circular Collider, and others. To some extent, this call corresponds to an international movement to reduce carbon dioxide emissions. Furthermore, an improvement in efficiency may result in significant savings in the machine's operating costs (electricity), as well as the ability to downsize the power plant, resulting in a decrease in the machine's initial investment cost [3].

An RF klystron amplifier capable of producing several megawatts of power is a common component in the RF power generation chain. Most commercial high-power RF klystrons now on the market have electronic efficiencies ranging between 40 and 55 percent, with the overwhelming majority of them operating in this range. Currently, only a small number of klystrons on the market are capable of functioning at a rate of 65 percent or higher efficiency. Achieving the greatest peak/average RF power was more essential for the scientific community than achieving high efficiency, and so the klystron developers focused their efforts on achieving the highest peak/average RF power rather than on delivering high efficiency.

At the time of writing, we are aware of just two tubes that were built and operated at electronic efficiency in excess of 70%. These are: 1) a 15 kW Continuous Wave (CW) L-band transmitter (with an 80% efficiency), which was constructed in 1984; and 2) a 50 kW Continuous Wave (CW) S-band transmitter (with an 80% efficiency), which was built in 1970. However, a thorough investigation into how to attain even greater electronic efficiency is still required, which may lead to realistic possibilities for building a very high-efficiency klystron in the near future. This work has just recently begun, and it involves combining the ideas of clustered bunching and regularised bunching that were previously suggested. With the introduction of the new concept of a non-monotonic bunching method, as well as the new notion of optimum lumped bunching length (LBL) as a generic parameter, the field has progressed significantly. In this article, we report the results of further research into klystrons with very high RF power conversion efficiency (about 90%) [4].

The klystron was developed in order to avoid the transit-time issues that caused the operational limitations of triodes and tetrodes to be reached. Klystrons are the most efficient linear beam tubes available, and they are capable of delivering the greatest peak and average powers available in the industry. They are suitable across a very wide frequency range, ranging from low UHF (200 MHz) to high-band (W-band) (100 GHz). The gain of multi-cavity klystrons has the potential to be very high. Gains of 60 dB or even higher, as well as efficiency of 70 percent, are very uncommon in this industry. In klystrons, the maximum peak power is restricted by the rate of RF breakdown, which is a function of the pulse length. At 1-2 microsecond pulse durations, 75 MW has been achieved in the X-band1 and more than 150 MW has been achieved in the S-band. Because klystron collectors may be made arbitrarily big, average power is a function of body cooling in this configuration.

A CW power of one megawatt has been achieved on the X-Band. When compared to traveling-wave tubes, the disadvantage of klystrons is that they have a limited band of operation (TWTs, see Chap. 4). Only TWTs are appropriate for a wide range of radar applications as well as for all electronic countermeasures (against radar). It is feasible to achieve limited klystron broad-banding in all cases, which makes klystrons suitable for some communication applications. In order to achieve a broad bandwidth in a klystron, low beam impedance (i.e., high purveyance and/or high power) is required. Lower purveyance beams are utilised for better electron optics at extremely high powers or high frequencies, while higher purveyance beams are employed at lower powers or lower frequencies. One percent bandwidth for continuous-wave klystrons may be challenging to achieve under such conditions. At S-band, 10 percent bandwidth is achievable with pulsed power of a few megawatts [5]. Low-power klystrons, especially reflex oscillators, have long since lost the fight against solid-state alternatives in radar and communication equipment. Solid-state devices, which are unable to generate competitive powers at millimetre-wave frequencies, are unlikely to be able to replace millimetre-wave klystron amplifiers, which can produce many tens of watts of average power. Tracking the development of klystrons and their uses throughout the course of the twentieth century is interesting. The triode was developed by DeForest in 1906, but arc-based Morse-code transmitters were still in use as late as 1912, according to some sources. Although wireless communication was present during World War I, the super-heterodyne receiver was not developed until 1918. (Armstrong).

Higher frequencies were clearly desired by 1930, and it was obvious to everyone that the transit-time limits of triodes and tetrodes would prohibit them from delivering sufficient power for new applications. After then, the hunt for additional RF sources started in earnest. Prior to World War II, the entire amount of radio frequency spectrum accessible was about 100 MHz (approximately 10 TV channels). RF sources are now available that can take use of a spectrum that is 1000 times broader than it was before. Klystrons are currently in use, or in the process of being developed, throughout the whole electromagnetic spectrum. This is not the case with any other kind of microwave power source, though. The discovery of radar spurred interest in microwaves, which resulted in the development of the cavity magnetron, which enabled the development of airborne radar and contributed to the victory of the Allies in World War II. During World War II, only low-power klystrons, usually known as "reflex" klystrons, were used. It was for particle accelerators that high-power klystrons were developed in the first place; the first megawatt klystron was conceived and constructed at Stanford University for this purpose. TWTs and electronic countermeasures (ECMs) were developed as a result of radar. In order to achieve magnetic fusion, millimetre wavelengths were needed, which led to the invention of gyrotrons in Russia [6].

1.1 Optimization Employing MOGA:

Enhancement of GA. In the same way that other improvement techniques do, a study from a group of people (recreation data sources) and plans (recreation outputs) are used to reflect the available space in the same way. The advanced target in the klystron system is both efficiency and maximum length, which is why a MOGA based on NSGA-II is being introduced. Due to the fact that NSGA-II provides a superior estimate for arrangement, exclusiveness of fuses and that no sharing parameter should be chosen from the previous one, it is a reasonable calculation for our role as a discovery quest method. When the public is created, the population is organised on each front based on non-mastery, and each person is assigned a serial value based on their position in the population. The establishment of an extra rank worth swarming separation is done for each person. An increase in population diversity would result from the enormous typical swarming division that occurs in the population.

1.2 BAC Procedure:

It appears from the presentation of the BAC portion that the current PV3050 klystron could provide increased productivity from the current 45 percent to a higher inferable value. In order to account for the two second consonant pits, four additional BAC pits were presumably added to the float tube. The Klystron structure may be represented by a variety of distinct codes. AJDISK, a one-dimensional (1-D) code, is used to drastically advance the parameters of the cylinder (for example, cavity detuning and exit hole output Q). The impact of the attractive field and beam profile is validated using a two-dimensional (2-D) code in the same manner (e.g., FCI). Finally, the cylinder is rebuilt with the help of a PIC code.

The FCI and Enchantment are used to confirm that the BAC-based structure is correct. When designing 2-D codes, the characteristics of the electron arm and the attractive field should be taken into consideration first and foremost. klystrons with high frequencies and high strengths have shown to be useful in the development of lightweight particle accelerators, high-resolution radars, and efficient data transmission networks, among many other applications. Because of the decrease in individual RF cell cavity impedances, the klystron performance of many linear beam systems gradually degrades as the operating frequency of the system increases. In order to mitigate this degradation, coupled cell designs should be used since they extend the field of beam and wave interaction. In order to get an accurate simulation of the klystron and cell structure, it is necessary to use PIC codes, which are both resource and time demanding [7].

The coupling mode theory has been investigated and generalised in order to shorten the Klystron design period in such a manner that the dynamic range of the dynamically coupled cavity system and its interaction with the packed electron beam can be predicted. These novel techniques have been used to the KlyC simulation programmes for big signal klystron klystrons. Modern technique is being shown via the setup and optimization of a Ku band, also known as a low-voltage clystron, it is believed. For KlyC simulations, CST PIC has been extensively evaluated, with good (within 1 percent) support provided by both codes, although KlyC is considerably quicker (within 100 times).

1.3 The Gun and The Solenoid:

The PV3050 weapon provides the majority of the information needed to create the particle gun model for the arranged BAC klystron. With an applied voltage of 310 kV, the MAGIC and DGUN codes are utilised to duplicate the commands of the arms, which are controlled by the computer. The solenoids in BAC are mostly based on the PV3050 klystron, which is a semiconductor device. There are a total of eight solenoids in use in the PV3050 klystron, which is a large number. That step involves a second use of the centring magnet, this time using the "POISSON SUPERFISH code."

1.4 Simulation of A Cylinder:

The parameters of electron guns, as well as the comparative attractive field, are utilised in the two-dimensional code. Because it is less complex than the MAGIC algorithm, the FCI code is built first, rather than the other way around. It should be noted that the separations between the penultimate pit and the exhaust cavity were increased by about 5 cm when it was found that efficiency could be enhanced even further under these conditions. This is evident in both instances, as shown by the beam profiles for contrast and PV3050, which show more particles gathered by the BAC tube at the output cavity.

The FCI algorithm predicted that the PV3050 and the BAC klystron would have the highest intensity efficiencies, with 44 percent and 68 percent, respectively. It is possible to comprehend an across-the-board replication using the Enchantment code, which guarantees that the pistol, centred attractive region, and depression cylinders may all be duplicated at the same time. Whatever the case, we should first capture the beam data from the GUN outlet district and then import this beam data from the klystron tubes delta, as is evident from the limited time we have available to us. Sorcery's projected productivity in the immersion stage, on the other hand, is about 52 percent (about 15 percent lower than that of FCI and AJDISK), according to the predictions. Enchantment and FCI fluxes were not well recognised at the time.

The position of the Enchantment code output pit in order to obtain the highest level of quality possible. Immediately before the second symphonic trap, it is possible to observe that the two codes are in mutual understanding. Despite this, the flows seem distinct once the pre-penultimate cavity has been reached. The task size of the MAGIC code has been restricted since the impact has not been substantially altered, as it might have been. It was also possible to alter the detuning of the second and penultimate symphonies, as well as the penultimate cavities to a certain degree, but only at the expense of high efficacy [8].

1.5 Klystron's CPD Methods:

A protective circuit must be placed between the body and the collecting circuit in order to separate it from the body (ground). The high voltage (Vc) supplied to the hole between the collecting circuit and the body during the recovery of the electrical vitality structure after it has exhausted electron beam as a result of producing Rf power. klystron participation causes a huge amount of energy to be dispersed in the depressions at the soaking operation due to electromagnetic interaction between the electron beam and the surrounding matter. Consequently, the authority potential will not be extended to the lower optimal point of appropriation of the spent electron beam, which is typically in the pits reached by the reverse electrons, as is often the case. It is necessary to limit the klystron operating mode to the UN-immerse condition with high cathode voltage in order to apply the potential that may have a beneficial impact. The Vk and Vc ratios indicate how much more efficient a system is. The sufficiency of Vc is dependent on the transmission of the potency of the wasted electron beam, at which point the sufficiency of Vc must be controlled in order to maintain the most intense power running capabilities [9]. The arrangement surrounding the CPD hole is made entirely of dielectric materials in order to keep the collector contained inside the body. During the activity, the high voltage of Vc is applied to a physical hole that has been created. Three issues must be addressed in order for this position to have an impact on the operation. There are three types of RF leakage: (a) the corona discharge and breakdown that occurs around the earthenware production protector and the exterior of the klystron, (b) the physical hole's RF leakage that occurs between dielectric components, and (c) the radiation shield structure that covers the top of the klystron [10].

2. DISCUSSION

Output circuits consisting of numerous uncoupled extraction cavities provide a feasible alternative solution to the issue of generating repetitively-pulsed high peak powers over relatively long pulse widths at high frequencies by using multiple uncoupled extraction cavities. They are straightforward and straightforward in their conception. It has been shown experimentally that the electron beam can maintain its bunched state while it passes through the different extraction gaps. Because the cavities are isolated and independent of one another, they may each be customised to meet a specific need while being free of many of the difficulties that can arise in linked systems. The efficiency of 36% stated here is not the best that can be achieved in this situation. According to computer models, an efficiency of 45 percent for X-band at the 100 MW level is very achievable with additional design refinement and refining. In the context of modelling interaction setups such as those described here, these simulations have proved to be a valuable and dependable resource.

The additional complexity required in using this method in situations where the output powers must be combined is a disadvantage for applications where the output powers must be mixed. This is a minor issue when dealing with two extraction cavities when the excursions in operating parameters are not too great compared to other cases. An extraction system with four cavities, on the other hand, is better suited for operation with fixed frequency and voltage as well as radio frequency driving since the output phases change more quickly with changes in operating parameters. Fixed parameters eliminate the need to adjust for variations in output phase more than once, allowing the individual outputs to be merged in a more efficient manner. When high power phase shifters are placed in the output system, the fixed-parameter limitation may be alleviated, on the other hand.

In previous comparative assessments of window materials, polycrystalline alumina, sapphire, beryllia, grooved quartz, and pyrolitic boron-nitride were found to be the best choices, with polycrystalline alumina being the best option. All of the alternatives, with the exception of alumina, have one or more properties that make them unsuitable for use in SLAC klystrons. Sapphire is unaffordable at this price point. Beryllia is a plant that has the potential to be a safety concern. In part, this is due to the low thermal expansion coefficient of both grooved quartz and pyrolitic boron-nitroride, which makes sealing them very difficult. As possible options for other microwave window applications, all of these materials seem to be more suitable for use on the SIXC klystron than alumina, which looks to be the most suitable.

Alumina windows, on the other hand, must first be coated with titanium oxides before they can be depended upon to function properly. Work should be done to identify the mechanisms and causes of window failure; this knowledge would allow for a better definition of window material specifications as well as for the identification of improvements or modifications to existing dielectric materials that would make them more suitable for use in windows. Toward a better knowledge of the unique physical characteristics and limits of different materials, particularly alumina, a portion of this work should be devoted to research and development. On a more practical level, ongoing efforts will be made to improve the control of window coating, with the ultimate goal of eliminating the need for window pretesting, which is now required. The comparative material assessment is continuing, this time with the testing of enhanced window glass. When new materials or better versions of materials that have previously been examined become available, they may be evaluated as alternatives.

3. CONCLUSION

The high-competency klystron design is a significant source of worry. The klystron enhancement shown in this article is based on the observation of 1D AJDISK with MOGA in this paper. We can observe and discuss the progression of klystron 6-cavtiy and klystron 7-depression as they develop in time. In 2013, a prototype CPD klystron was built using an existing Toshiba E3786 klystron as a basis for development. (TRISTAN and KEKB were utilised in this study.) The goal is to develop a CPD proof-of-concept for the use of CW klystrons in the unsaturated part of the spectrum. Currently, work is being done on the RF construction and radiation shield that will be used to advance the CPD klystron. Following the completion of Step 2 of Super KEKB, a test to demonstrate the evidence-guideline of the CPD method for klystron will be conducted. This CPD Klystron would not be used in the Super KEKB version of the game. It requires the commercial reasonability of KPS (Klystron Power Supply) to be enhanced in order to be brought up to date.

In 2013, the new Toshiba E3786 Klystron was built specifically for recycling. (The purpose of the CPD is to demonstrate that a CW klystron may be utilised in an unsaturated field.) (It was used in the production of TRISTAN and KEKB.) The shield rf and radiation arrangement of the CPD klystron have now been optimised for optimal performance. In order to demonstrate proof of concept for the CPD technique for Klystron, it is anticipated that Phase 2 of the Super-KEKB test will be completed. Furthermore, this CPD klystron will not be included in the Super-KEKB configuration. It is essential for the optimization of commercial viability that KPS (Klystron Power Supply) production be carried out properly. At the moment, it is a project for the future.

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