第２章　研究活動

2-1 平成 31／令和元年度活動スケジュール

2−1−1 国内会議

○ 2019 年度電気学会産業応用部門大会 ..... 2019 年 8 月
○ 2019 年（第 37 回）電気設備学会全国大会 ..... 2019 年 8 月
○ 令和元年電気学会　電力・エネルギー部門大会 ..... 2019 年 9 月
○ 令和元年度電気・電子・情報関係学会東海支部連合大会 ..... 2019 年 9 月
○ 2019 年電気学会電力技術／電力系統技術合同研究会 ..... 2019 年 9 月
○ 2019(令和元)年度 JSES 研究発表会（日本太陽エネルギー学会）..... 2019 年 10 月
○ 放電・プラズマ・パルスパワー／開閉保護／高電圧合同研究会 ..... 2019 年 12 月
○ 令和 2 年電気学会全国大会 ..... 2020 年 3 月
○ 空気調和・衛生工学会中部支部 2019 年度 第 21 回学術研究発表会 ..... 2020 年 3 月

2−1-2 国際会議

○ ICDCM 2019 (IEEE International Conference on DC Microgrids)..... 2019 年 5 月
○ ICPE 2019-ECCE (International Conference on Power Electronics)..... 2019 年 5 月
○ IFAC CSGRES 2019 (International Federation of Automatic Control Workshop on Control of Smart Grid and Renewable Energy Systems) ..... 2019 年 6 月
○ ICEE Conference 2019 (The International Council on Electrical Engineering Conference) ..... 2019 年 7 月
○ ECTI-CON 2019 (International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology) ..... 2019 年 7 月
○ ICEPE-ST 2019 (International Conference on Electric Power Equipment - Switching technology)..... 2019 年 10 月
○ IEEE VPPC 2019 (IEEE Vehicle Power and Propulsion Conference) ..... 2019 年 10 月
○ ICMaSS 2019 (International Conference on Materials and Systems for Sustainability) ..... 2019 年 11 月
○ IWGESD 2019 (International Workshop on Green Energy System and Devices)..... ..... 2019 年 12 月

2−1-3 その他

○ 2019 M-J SEMINAR..... 2019 年 12 月

2-2 学会・公表研究論文等

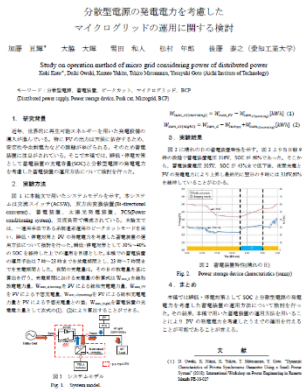
ここには参加した各学会等の名称等を記載し，公表論文タイトル等は後の一覧で示す。

○ 2019 年度電気学会産業応用部門大会

会　期　2019 年 8 月 20 日～22 日

会　場　長崎大学　文教キャンパス

主　催　電気学会

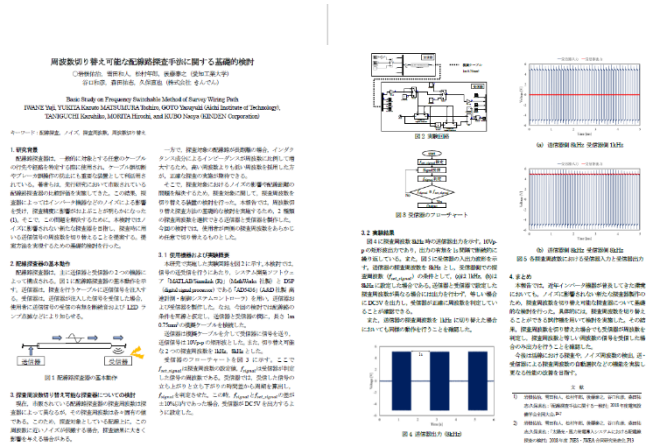

分散型電源の発電電力を考慮した
マイクログリッドの運用に関する検討

○ 2019 年（第 37 回）電気設備学会全国大会

会　期　2019 年 8 月 29 日～8 月 30 日

会　場　福岡工業大学

主　催　電気設備学会

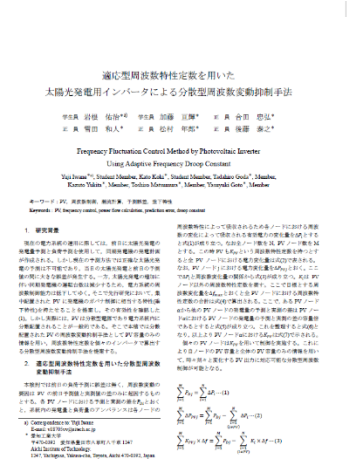

周波数切り替え可能な配線路探査手法に関する基礎的検討

○ 令和元年電気学会　電力・エネルギー部門大会

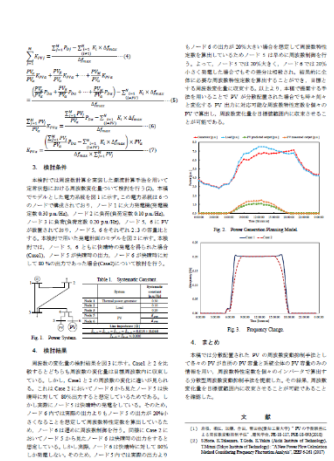
会　期　2019 年 9 月 3 日～6 日

会　場　広島大学　五日市キャンパス

主　催　電気学会


適応型周波数特性定数を用いた
太陽光発電用インバータによる分散型周波数変動抑制手法

Frequency Fluctuation Control Method by Photovoltaic Inverter
Using Adaptive Frequency Droop Constant

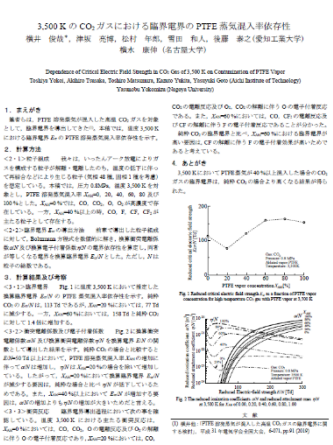


○ 令和元年度電気・電子・情報関係学会東海支部連合大会

会　期　2019 年 9 月 3 日～4 日

会　場　名城大学

主　催　電気学会東海支部・電子情報通信学会東海支部・情報処理学会東海支部・日本電気協会中部支部・西日本電信電話株式会社・NHK 名古屋放送局・名城大学・名古屋大学

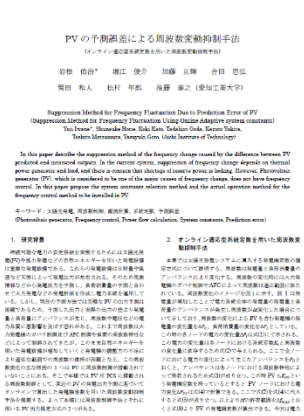

3,500 K の CO_2 ガスにおける臨界電界の PTFE 蒸気混入率依存性

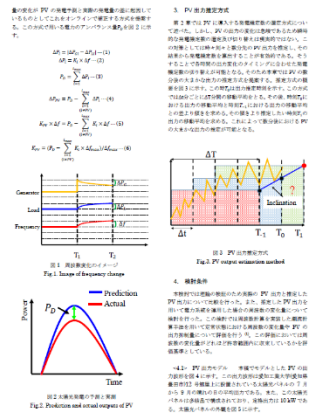
○ 2019 年電気学会電力技術／電力系統技術合同研究会

会　期　2019 年 9 月 19 日～20 日

会　場　琉球大学　千原キャンパス

主　催　電気学会



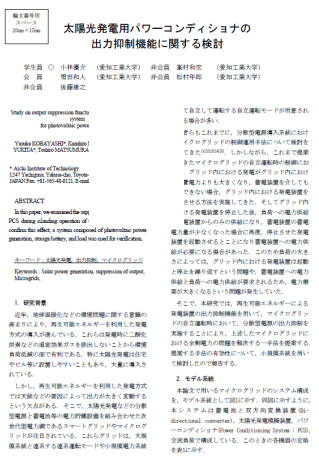


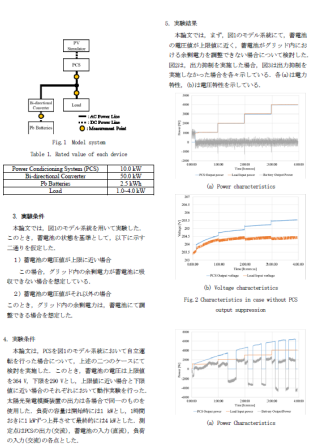
○ 2019(令和元)年度 JSES 研究発表会

会　期　2019 年 10 月 16 日～10 月 18 日

会　場　リンクステーションホール青森

主　催　日本太陽エネルギー学会



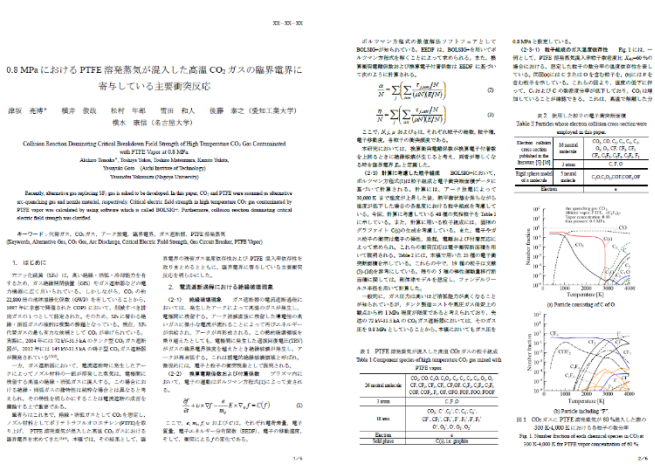


○ 放電・プラズマ・パルスパワー／開閉保護／高電圧合同研究会

会　期　2019 年 12 月 5 日～6 日

会　場　三重県 伊勢市観光文化会館

主　催　電気学会



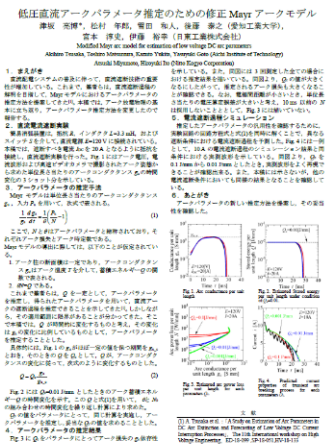
○ 令和 2 年電気学会全国大会

会　期　2020 年 3 月 11 日～13 日

会　場　東京電機大学　東京千住キャンパス

主　催　電気学会

※新型コロナウイルス感染症のため
発表は中止



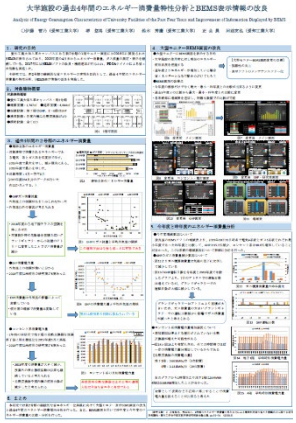
○　空気調和・衛生工学会中部支部 2019 年度 第 21 回学術研究発表会

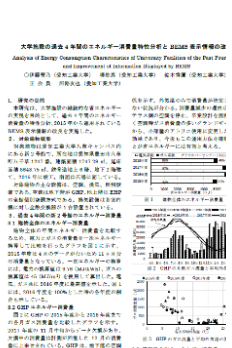
会　期　2020 年 3 月 18 日

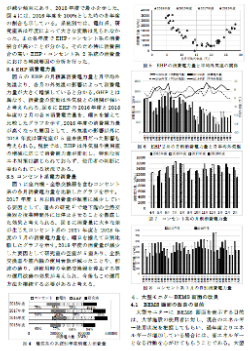
会　場　名古屋市　東桜会館

主　催　空気調和・衛生工学会

※新型コロナウイルス感染症のため
発表は中止





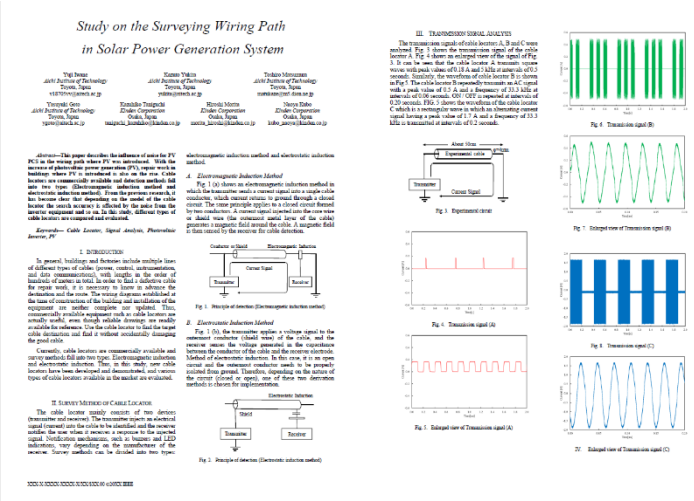


○　ICDCM 2019 (IEEE International Conference on DC Microgrids)

会　期　2019 年 5 月 20 日～23 日

会　場　島根県松江市　くにびきメッセ

主　催　IEEE

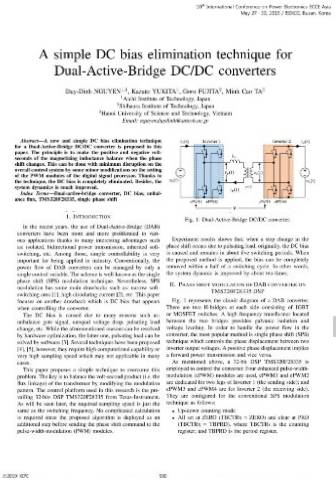


○ ICPE 2019-ECCE (International Conference on Power Electronics)

会　期　2019 年 5 月 27 日～30 日

会　場　BEXCO, Busan, Korea

主　催　KIPE

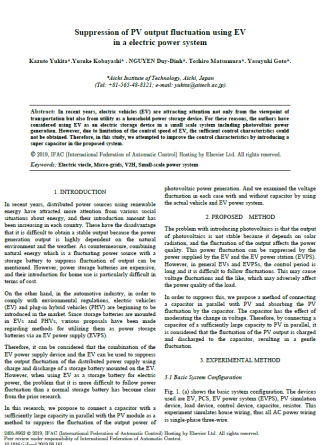


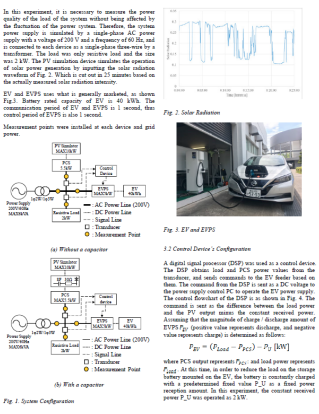
○ IFAC CSGRES 2019

(International Federation of Automatic Control Workshop on Control of Smart Grid and Renewable Energy Systems)

会　期　2019 年 6 月 10 日～12 日

会　場　Hyatt Regency jeju, Korea





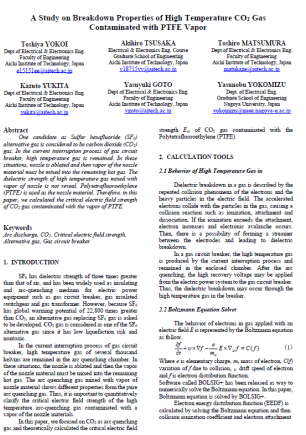
○ The ICEE Conference 2019

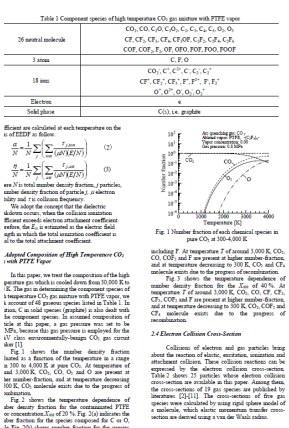
(The International Council on Electrical Engineering Conference)

会　期　2019 年 7 月 2 日～6 日

会　場　The Hong Kong Institution of Engineers (HKIE)

主　催　The Hong Kong Institution of Engineers (HKIE)


A Study on Breakdown Properties of High Temperature CO_2 Gas Contaminated with PTFE Vapor



○ ECTI-CON 2019

(International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology)

会　期　2019 年 7 月 10 日～13 日

会　場　Pattaya,Thailand

主　催　ECTI


Distributed Frequency Suppression Method Using Inverter for Photovoltaic Power Generation

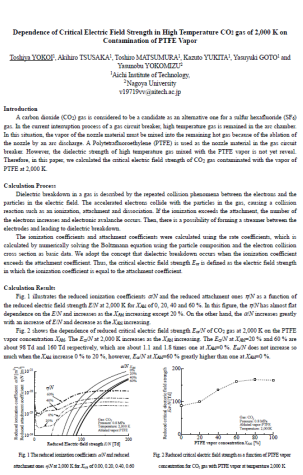
○ ICEPE-ST 2019

(2019 5th International Conference on Electric Power Equipment – Switching Technology)

会　期　2019 年 10 月 13 日～16 日

会　場　北九州国際会議場

主　催　電気学会


Dependence of Critical Electric Field Strength in High Temperature CO_2 gas of 2,000 K on Contamination of PTFE Vapor

Toshiya YOKOJI[1], Akiharu TSUSAKA[1], Toshiro MATSUMURA[1], Kazuto YUKITA[1], Yasuyuki GOTO[2] and Yasunobu YOKOMIZU[2]

[1]Aichi Institute of Technology,
[2]Nagoya University
v1P17@ivy.aitech.ac.jp

Introduction

A carbon dioxide (CO_2) gas is considered to be a candidate as an alternative one for a sulfur hexafluoride (SF_6) gas. In the current interruption process of a gas circuit breaker, high temperature gas is remained in the arc chamber. In this situation, the vapor of the nozzle material must be mixed into the remaining hot gas because of the ablation of the nozzle by an arc discharge. A Polytetrafluoroethylene (PTFE) is used as the nozzle material in the gas circuit breaker. However, the dielectric strength of high temperature gas mixed with the PTFE vapor is not yet revealed. Therefore, in this paper, we calculated the critical electric field strength of CO_2 gas contaminated with the vapor of PTFE at 2,000 K.

Calculation Process

Dielectric breakdown in a gas is decribed by the repeated collision phenomena between the electrons and the particles in the electric field. The accelerated electronic collide with the particles in the gas, causing a collision reaction such as an ionization, attachment and dissociation. If the ionization exceeds the attachment, the number of the electrons increases and electronic avalanche occurs. Then, there is a possibility of forming a streamer between the electrodes and leading to dielectric breakdown.

The ionization coefficient and attachment coefficient were calculated using the rate coefficient, which is calculated by unsteadily solving the Boltzmann equation using the particle composition and the electron collision cross section as basic data. We adopt the concept that dielectric breakdown occurs when the ionization coefficient exceeds the attachment coefficient. Thus, the critical electric field strength E_0 is defined as the electric field strength in which the ionization coefficient α equal to the attachment coefficient.

Calculation Results

Fig. 1 illustrates the reduced ionization coefficients: α/N and the reduced attachment ones: η/N as a function of the reduced electric field strength E/N at 2,000 K for Σ_{PTFE} of 0, 20, 40 and 60 %. In this figure, the η/N has almost flat dependence on the E/N and increases as the Σ_{PTFE} increasing except 20 %. On the other hand, the α/N increases greatly with an increase of E/N and decrease as the Σ_{PTFE} increasing.

Fig. 2 shows the dependence of reduced critical electric field strength E_0/N of CO_2 gas at 2,000 K on the PTFE vapor concentration Σ_{PTFE}. The E_0/N at 2,000 K increases as the Σ_{PTFE} increasing. The E_0/N at Σ_{PTFE}=20 % and 60 % are about 98 Td and 160 Td respectively, which are about 1.1 and 1.8 times one at Σ_{PTFE}=0 %. E_0/N does not increase so much when the Σ_{PTFE} increase 0 % to 20 %, however, E_0/N at Σ_{PTFE}=60 % greatly higher than one at Σ_{PTFE}=0 %.

Fig. 1 The reduced ionization coefficient: α/N and reduced attachment one: η/N at 2,000 K for Σ_{PTFE} of 0.00, 0.20, 0.40, 0.60

Fig. 2 Reduced critical electric field strength as a function of PTFE vapor concentration for CO_2 gas with PTFE vapor at temperature 2,000 K

○ IEEE VPPC 2019 (IEEE Vehicle Power and Propulsion Conference)

会　期　2019 年 10 月 14 日～17 日

会　場　Hanoi, Vietnam

主　催　IEEE


energies

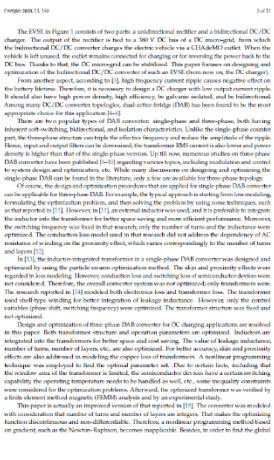
Article

Design and Optimization of Three-Phase Dual-Active-Bridge Converters for Electric Vehicle Charging Stations

Duy-Dinh Nguyen [1,2,*], Ngoc-Tam Bui [2,3] and Kazuto Yukita [1]

[1] Aichi Institute of Technology, Toyota 470-0356, Japan; yukita@aitech.ac.jp
[2] Hanoi University of Science and Technology, Hanoi, Vietnam; tambui@shisaurt-it.ac.jp
[3] Shibaura Institute of Technology, Tokyo 135-8548, Japan
* Correspondence: nguyendinh@aitech.ac.jp; Tel.: +81-0565-48-8121

Received: 27 November 2019; Accepted: 25 December 2019; Published: 27 December 2019

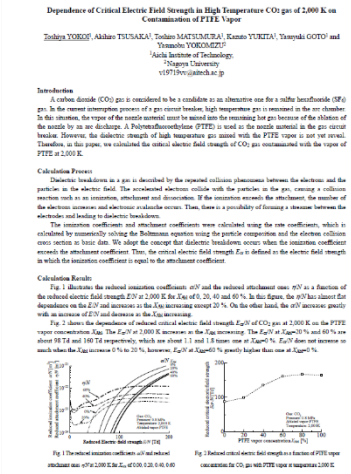


○ ICMaSS 2019 (International Conference on Materials and Systems for Sustainability)

会　期　2019 年 11 月 1 日～3 日

会　場　名古屋大学

主　催　ICMaSS


Dependence of Critical Electric Field Strength in High Temperature CO_2 gas of 2,000 K on Contamination of PTFE Vapor

Toshiya YOKOI[1], Akihiro TSUSAKA[1], Toshiro MATSUMURA[1], Kazuto YUKITA[1], Yasuyuki GOTO[2] and Yasunobu YOKOMIZU[2]
[1]Aichi Institute of Technology,
[2]Nagoya University
yi19719vv@aitech.ac.jp

Introduction
A carbon dioxide (CO_2) gas is considered to be a candidate as an alternative one for a sulfur hexafluoride (SF_6) gas. In the current interruption process of a gas circuit breaker, high temperature gas is ceramized in the arc chamber. In this situation, the vapor of the nozzle material must be mixed into the remaining hot gas because of the ablation of the nozzle by an arc discharge. A Polytetrafluoroethylene (PTFE) is used as the nozzle material in the gas circuit breaker. However, the dielectric strength of high temperature gas mixed with the PTFE vapor is not yet reveal. Therefore, in this paper, we calculated the critical electric field strength of CO_2 gas contaminated with the vapor of PTFE at 2,000 K.

Calculation Process
Dielectric breakdown in a gas is described by the repeated collision phenomena between the electrons and the particles in the electric field. The accelerated electrons collide with the particles in the gas, causing a collision reaction such as an ionization, attachment and dissociation. If the ionization exceeds the attachment, the number of the electrons increases and electronic avalanche occurs. Then, there is a possibility of forming a streamer between the electrodes and leading to dielectric breakdown.
The ionization coefficients and attachment coefficients were calculated using the rate coefficients, which is calculated by numerically solving the Boltzmann equation using the particle composition and the electron collision cross section as basic data. We adopt the concept that dielectric breakdown occurs when the ionization coefficient exceeds the attachment coefficient. Then, the critical electric field strength E_k is defined as the electric field strength in which the ionization coefficient is equal to the attachment coefficient.

Calculation Result
Fig. 1 illustrates the reduced ionization coefficients α/N and the reduced attachment ones η/N as a function of the reduced electric field strength E/N at 2,000 K for X_{H2} of 0, 20, 40 and 60 %. In this figure, the η/N has almost flat dependence on the E/N and increases at the X_{H2} increasing except 20 %. On the other hand, the α/N increases greatly with an increase of E/N and decrease as the X_{H2} increasing.
Fig. 2 shows the dependence of reduced critical electric field strength E_k/N of CO_2 gas at 2,000 K on the PTFE vapor concentration X_{PE}. The E_k/N at 2,000 K increases as the X_{PE} increasing. The E_k/N at X_{PE}=20 % and 60 % are about 98 Td and 160 Td respectively, which are about 1.1 and 1.8 times one at X_{PE}=0 %. E_k/N does not increase so much when the X_{PE} increase 0 % to 20 %, however, E_k/N at X_{PE}=60 % greatly higher than one at X_{PE}=0 %.

Fig. 1 The reduced ionization coefficients α/N and reduced attachment ones η/N at 2,000 K for X_{H2} of 0.00, 0.20, 0.40, 0.60

Fig. 2 Reduced critical electric field strength as a function of PTFE vapor concentration for CO_2 gas with PTFE vapor at temperature 2,000 K

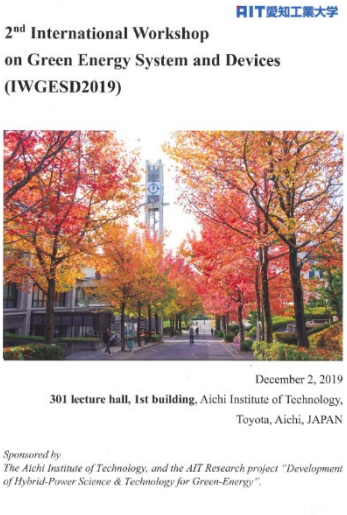
○ IWGESD 2019

(International Workshop on Green Energy System and Devices)

会　期　2019 年 12 月 2 日

会　場　愛知工業大学

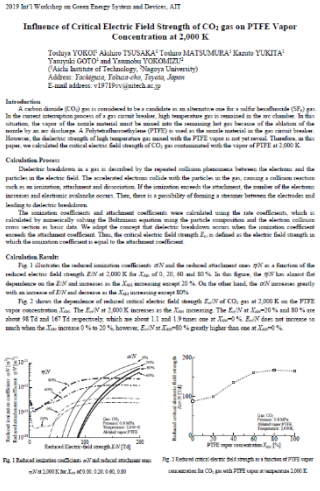
主　催　愛知工業大学


AIT愛知工業大学

2nd International Workshop
on Green Energy System and Devices
(IWGESD2019)

December 2, 2019
301 lecture hall, 1st building, Aichi Institute of Technology,
Toyota, Aichi, JAPAN

Sponsored by
The Aichi Institute of Technology, and the AIT Research project "Development of Hybrid-Power Science & Technology for Green-Energy".


2019 Int'l Workshop on Green Energy System and Devices, AIT

Influence of Critical Electric Field Strength of CO_2 gas on PTFE Vapor Concentration at 2,000 K

Toshiya YOKOI[1], Akihiro TSUSAKA[1], Toshiro MATSUMURA[1], Kazuto YUKITA[1]
Yasuyuki GOTO[2] and Yasunobu YOKOMIZU[2]
([1]Aichi Institute of Technology, [2]Nagoya University)
Address: Tachigaya, Fuhau-cho, Toyota, Japan
E-mail address: yi19719vv@aitech.ac.jp

Introduction
A carbon dioxide (CO_2) gas is considered to be a candidate as an alternative one for a sulfur hexafluoride (SF_6) gas. In the current interruption process of a gas circuit breaker, high temperature gas is ceramized in the arc chamber. In this situation, the vapor of the nozzle material must be mixed into the remaining hot gas because of the ablation of the nozzle by an arc discharge. A Polytetrafluoroethylene (PTFE) is used as the nozzle material in the gas circuit breaker. However, the dielectric strength of high temperature gas mixed with the PTFE vapor is not yet reveal. Therefore, in this paper, we calculated the critical electric field strength of CO_2 gas contaminated with the vapor of PTFE at 2,000 K.

Calculation Process
Dielectric breakdown in a gas is described by the repeated collision phenomena between the electrons and the particles in the electric field. The accelerated electrons collide with the particles in the gas, causing a collision reaction such as an ionization, attachment and dissociation. If the ionization exceeds the attachment, the number of the electrons increases and electronic avalanche occurs. Then, there is a possibility of forming a streamer between the electrodes and leading to dielectric breakdown.
The ionization coefficients and attachment coefficients were calculated using the rate coefficients, which is calculated by numerically solving the Boltzmann equation using the particle composition and the electron collision cross section as basic data. We adopt the concept that dielectric breakdown occurs when the ionization coefficient exceeds the attachment coefficient. Then, the critical electric field strength E_k is defined as the electric field strength in which the ionization coefficient is equal to the attachment coefficient.

Calculation Result:
Fig. 1 illustrates the reduced ionization coefficients α/N and the reduced attachment ones η/N as a function of the reduced electric field strength E/N at 2,000 K for X_{H2} of 0, 20, 60 and 80 %. In this figure, the η/N has almost flat dependence on the E/N and increases at the X_{H2} increasing except 20 %. On the other hand, the α/N increases greatly with an increase of E/N and decrease as the X_{H2} increasing except 80%.
Fig. 2 shows the dependence of reduced critical electric field strength E_k/N of CO_2 gas at 2,000 K on the PTFE vapor concentration X_{PE}. The E_k/N at 2,000 K increases as the X_{PE} increasing. The E_k/N at X_{PE}=20 % and 80 % are about 98 Td and 167 Td respectively, which are about 1.1 and 1.9 times one at X_{PE}=0 %. E_k/N does not increase so much when the X_{PE} increase 0 % to 20 %, however, E_k/N at X_{PE}=60 % greatly higher than one at X_{PE}=0 %.

Fig. 1 Reduced ionization coefficients α/N and reduced attachment ones η/N at 2,000 K for X_{H2} of 0.00, 0.20, 0.60, 0.80

Fig. 2 Reduced critical electric field strength as a function of PTFE vapor concentration for CO_2 gas with PTFE vapor at temperature 2,000 K

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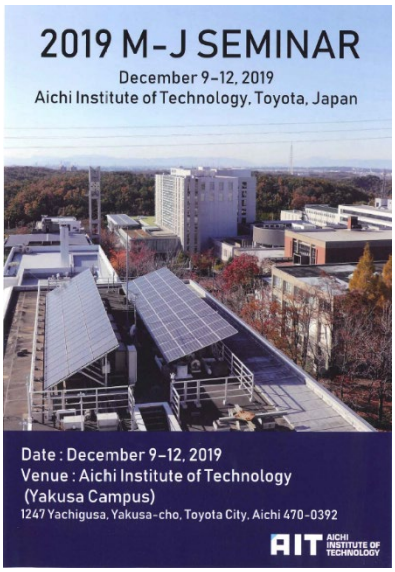

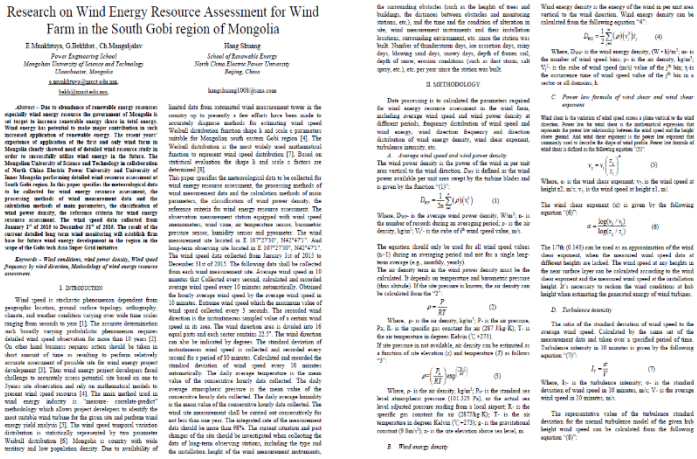

Research on Wind Energy Resource Assessment for Wind Farm in the South Gobi region of Mongolia

E.Munkhtuya, G.Bekhbat, Ch.Munguljaliv
Power Engineering School
Mongolian University of Science and Technology
Ulaanbaatar, Mongolia
munkhtuya_e@must.edu.mn
bekh@must.edu.mn

Hang Shuang
School of Renewable Energy
North China Electric Power University
Beijing, China
hangshuang1908@ncepu.com

Abstract **– Due to abundance of renewable energy resources especially wind energy resource the government of Mongolia is set target to increase renewable energy share in total energy. Wind energy has potential to make major contribution in such increased application of renewable energy. The recent years' experience of application of the first and only wind farm in Mongolia clearly showed need of detailed wind resource study in order to successfully utilize wind energy in the future. The Mongolian University of Science and Technology in collaboration of North China Electric Power University and University of Inner Mongolia performing detailed wind resource assessment in South Gobi region. In this paper specifies the meteorological data to be collected for wind energy resource assessment, the processing methods of wind measurement data and the calculation methods of main parameters, the classification of wind power density, the reference criteria for wind energy resource assessment. The wind speed data collected from January 1st of 2010 to December 31st of 2010. The result of the current detailed long term wind monitoring will establish firm base for future wind energy development in the region in the scope of the Gobi tech Asia Super Grid initiative.**

Keywords – Wind conditions, wind power density, Wind speed frequency by wind direction, Methodology of wind energy resource assessment.

I. INTRODUCTION

Wind speed is stochastic phenomenon dependent from geographic location, ground surface topology, orthography, climate, and weather condition varying over wide time scales ranging from seconds to year [1]. The accurate determination such broadly varying probabilistic phenomenon requires detailed wind speed observation for more than 10 years [2]. On other hand business oriented criteria should be taken in short amount of time as resulting to perform relatively accurate assessment of possible site for wind energy project development [3]. Thus wind energy project developers faced challenge to accurately assess potential site based on one to 3years site observation and rely on mathematical models to present wind speed resource [4]. The main method used in wind energy industry is measure – correlate-predict methodology which allows project developers to identify the most suitable wind turbine for the given site and perform wind energy yield analysis [5]. The wind speed temporal variation distribution is statistically represented by two parameter Weibull distribution [6]. Mongolia is country with wide territory and low population density. Due to availability of limited data from automated wind measurement tower in the country up to presently a few efforts have been made to accurately designe methods for estimating wind speed Weibull distribution function shape k and scale c parameter suitable for Mongolian south eastern Gobi region [4]. The Weibull distribution is the most widely used mathematical function to represent wind speed distribution [7]. Based on statistical evaluation the shape k and scale c factors are determined [8].

This paper specifies the meteorological data to be collected for wind energy resource assessment, the processing methods of wind measurement data and the calculation methods of main parameters, the classification of wind power density, the reference criteria for wind energy resource assessment. The observation measurement station equipped with wind speed measurement, wind vane, air temperature sensor, barometric pressure sensor, humidity sensor and pyranometer. The wind measurement site located in E 107°27'50", 3842'47"; And long-term observing site located in E 109°27'50", 3842'47"; The wind speed data collected from January 1st of 2013 to December 31st of 2015. The following data shall be collected from each wind measurement site. Average wind speed in 10 minutes that Collected every second, calculated and recorded average wind speed every 10 minutes automatically. Obtained the hourly average wind speed by the average wind speed in 10 minutes. Extreme wind speed which the maximum value of wind speed collected every 3 seconds. The recorded wind direction is the instantaneous sampled value of a certain wind speed in its area. The wind direction area is divided into 16 equal parts and each vector contains 22.5°. The wind direction can also be indicated by degrees. The standard deviation of instantaneous wind speed is collected and recorded every second for a period of 10 minutes. Calculated and recorded the standard deviation of wind speed every 10 minutes automatically. The daily average temperature is the mean value of the consecutive hourly data collected. The daily average atmospheric pressure is the mean value of the consecutive hourly data collected. The daily average humidity is the mean value of the consecutive hourly data collected. The wind site measurement shall be carried out consecutively for not less than one year. The integrated rate of the measurement data should be more than 90%. The current situation and past changes of the site should be investigated when collecting the data of long-term observing stations, including the type and the installation height of the wind measurement instruments, the surrounding obstacles (such as the height of trees and buildings, the distance between obstacles and monitoring stations, etc.), and the time and the condition of alteration in site, wind measurement instruments and their installation locations, surrounding environment, etc. since the station was built. Number of thunderstorm days, ice accretion days, misty days, blowing sand days, snowy days, depth of frozen soil, depth of snow, erosion conditions (such as dust storm, salt spray, etc.), etc. per year since the station was built.

II. METHODOLOGY

Data processing is to calculated the parameters required for wind energy resource assessment in the wind farm, including average wind speed and wind power density at different periods, frequency distribution of wind speed and wind energy, wind direction frequency and direction distribution of wind energy density, wind shear exponent, turbulence intensity, etc.

A. Average wind speed and wind power density

The wind power density is the power of the wind as per unit area vertical to the wind direction. D_{WP} is defined as the wind power available per unit area swept by the turbine blades and is given by the function "(1)":

$$D_{WP} = \frac{1}{2n}\sum_{i=1}^{n}(\rho)(V_i^3) \qquad (1)$$

Where, D_{WP}- is the average wind power density, W/m²; n- is the number of records during an averaging period; ρ- is the air density, kg/m³; V_i- is the cube of i^th wind speed value, m/s.

The equation should only be used for all wind speed values (i=1) during an averaging period and not for a single long-term average (e.g., monthly, yearly).

The air density term in the wind power density must be the calculated. It depends on temperature and barometric pressure (thus altitude). If the site pressure is known, the air density can be calculated from the "2":

$$\rho = \frac{P}{RT} \qquad (2)$$

Where, ρ- is the air density, kg/m³; P- is the air pressure, Pa; R- is the specific gas constant for air (287 J/kg·K); T- is the air temperature in degrees Kelvin (°C +273).

If site pressure is not available, air density can be estimated as a function of site elevation (z) and temperature (T) as follows "3":

$$\rho = \left(\frac{P_0}{RT}\right)\exp^{\left(\frac{-gz}{RT}\right)} \qquad (3)$$

Where, ρ- is the air density, kg/m³; P_0- is the standard sea level atmospheric pressure (101.325 Pa), or the actual sea level adjusted pressure reading from a local airport; R- is the specific gas constant for air (287J/kg·K); T- is the air temperature in degrees Kelvin (°C +273); g- is the gravitational constant (9.8m/s²); z- is the site elevation above sea level, m.

B. Wind energy density

Wind energy density is the energy of the wind in per unit area vertical to the wind direction. Wind energy density can be calculated from the following equation "4":

$$D_{WE} = \frac{1}{2}\sum_{i=1}^{n}(\rho)(v_i^3)f_i \qquad (4)$$

Where, D_{WE}- is the wind energy density, (W × h)/m²; m- is the number of wind speed bins; ρ- is the air density, kg/m³; V_i^3- is the cube of wind speed (m/s) value of the i^th bin; f_i-is the occurrence time of wind speed value of the i^th bin in a sector or all domains; h.

C. Power law formula of wind shear and wind shear exponent

Wind shear is the variation of wind speed across a plane vertical to the wind direction. Power law for wind shear is the mathematical expression that represents the power law relationship between the wind speed and the height above ground. And wind shear exponent is the power law exponent that commonly used to describe the shape of wind profile. Power law formula of wind shear is defined in the following equation "(5)":

$$v_2 = v_1\left(\frac{z_2}{z_1}\right)^{\alpha} \qquad (5)$$

Where, α- is the wind shear exponent; v_2 is the wind speed at height z2, m/s; v_1 is the wind speed at height z1, m/.

The wind shear exponent (α) is given by the following equation "(6)":

$$\alpha = \frac{\log(v_2 / v_1)}{\log(z_2 / z_1)} \qquad (6)$$

The 1/7th (0.143) can be used as an approximation of the wind shear exponent, when the measured wind speed data at different heights are lacked. The wind speed at any height in the near surface layer can be calculated according to the wind shear exponent and the measured wind speed at the installation height. It's necessary to reckon the wind conditions at hub height when estimating the generated energy of wind turbine.

D. Turbulence intensity

The ratio of the standard deviation of wind speed to the average wind speed. Calculated by the same set of the measurement data and taken over a specified period of time. Turbulence intensity in 10 minutes is given by the following equation "(7)":

$$I_t = \frac{\sigma}{V} \qquad (7)$$

Where, I_t- is the turbulence intensity; σ- is the standard deviation of wind speed in 10 minutes, m/s; V- is the average wind speed in 10 minutes, m/s.

The representative value of the turbulence standard deviation for the normal turbulence model of the given hub height wind speed can be calculated from the following equation "(8)":