Online ISSN : 2249-4596
Print ISSN : 0975-5861
DOI : 10.17406/GJRE

Global Journal of Researches in Engineering: F

Electrical and Electronic Engineering

Highlights

- Monopolar Patch Antenna
- Design and Improvement of Step
- Three Phase UPFC Regulator
- Design & Development of Electric

Discovering Thoughts, Inventing Future

Volume 16 Issue 4 Version 1.0

Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering

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Electrical and Electronics Engineering
Volume 16 Issue 4 (Ver. 1.0)

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Design and Improvement of Step Slotted Microstrip Monopolar Patch Antenna using Defected Ground Structure (DGS)

By Jovita Serrao & Nirav Patel
St. Francis Institute of Technology, India

Abstract- A new low profile and broadband monopolar patch antenna is proposed. Previously, long rectangular patch antennas have been designed with a compact structure and high gain, but these antennas do not have the required monopolar radiation pattern. On the other hand there have been patches designed to have wide bandwidth by employing thick substrates. However, the profile of such antennas may be too high for certain applications. We propose a low profile patch antenna with wide bandwidth, high gain, high directivity and monopole like radiation pattern. The proposed antenna has a bandwidth of 1.396% and gain of 4.75 dBi with monopole like radiation pattern at 5.156 GHz for an infinite ground plane. Using Defected Ground Structure (DGS) resonant frequencies are obtained at 3.836, 5.18 and 6.644 GHz, with bandwidth of 18.902% and gain of 8.66 dBi.

Keywords: excitation modes, low profile, monopolar patch antenna, coplanar waveguide fed (CPW), defected ground structure (DGS), omnidirectional, method of moments (MOM).

GJRE-F Classification : FOR Code: 100501

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Jovita Serrao [α] & Nirav Patel [σ]

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I. Introduction

Monopole antennas are widely used in wireless communication system, since they can provide omnidirectional radiation patterns [1]. In recent years the demands on mobile communication have grown rapidly. So, indoor wireless networks consisting of numerous indoor base station antennas have been mounted on the ceilings of many buildings and malls, thus there are stringent requirements on an antennas impedance bandwidth and physical size. Many types of monopole antenna are attractive for present wireless communication systems.

A typical monopole antenna is the quarter wavelength monopole antenna, whose length is equal to a quarter of the wavelength at the resonance frequency. The profile of a conventional monopole antenna is too high for some devices that have limited space for hiding the antenna. Microstrip antennas are popular for their low cost, light weight, easy fabrication, mass production and planar structure with low profile [1][2]. Because of the merits it is expected that microstrip antennas can be used to replace monopole antennas that have a high profile of about quarter wavelengths. A microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. Radiation from the patch can occur from the fringing fields between the periphery of the patch and the ground plane.

This paper is organized as follows. Section 1 mentions a brief introduction to the applications of monopole antenna. Various methods that have been implemented to design monopolar patch antennas and their drawbacks, is mentioned in Section 2. Section 3 explains the design of a novel low profile monopolar patch antenna. The number of resonant frequencies and the bandwidth is increased using Defected Ground Structure (DGS). The simulation and results are shown in Section 4. In this section we have also mentioned the effects of DGS. The paper is concluded in Section 5.

II. Monopolar Patch Antenna

Monopole antennas are widely used since they provide a vertical polarization and a conical radiation pattern. However, the profile of a conventional monopole antenna that has a quarter wavelengths is too high for some devices or applications that have limited space for hiding the antenna. Many excitation modes have been studied for circular disc and annular ring patches. A circular microstrip antenna can be used to replace vertical wire monopole [3]. However, the radius of this antenna is very large. Microstrip antennas including ground wire which connects the patch of the antenna to the ground plane can be used to obtain monopole like radiation pattern [4].Such an antenna has total height much less than a quarter wavelength of the centre operating frequency. However, this type of monopolar wire patch antenna has a narrow impedance bandwidth. To improve the bandwidth a planar rectangular monopole top-loaded with a shorted square or circular patch can be used [5]. The wire monopole and the ground wires [4] can be replaced by a planar rectangular monopole and ground rectangular plates respectively [5]. The profile of such an antenna is around $0.09_{\lambda 0,}$ which is much lower as compared to the quarter wavelength dipole. The bandwidth can further be increased by using a circular patch, because of the

Author α: St. Francis Institute of Technology Mumbai, India.
e-mail: joviserrao@gmail.com
Author σ: St. John College of Engineering & Technology Mumbai, India.
e-mail: niravkpatel28@gmail.com

relatively large patch size. The bandwidth of a probe fed patch antenna is limited by the inductance introduced by the coaxial feed in case of thick substrate. To improve the bandwidth and avoid drilling or soldering of the patch, a L-probe fed circular patch antenna can be used [6]. Such an antenna provides wide bandwidth and high gain with a profile of 0.13 λ_0. However, such antennas consist of air substrate, which are difficult to implement. Another inconvenience is that such antennas are larger in size as compared to quarter wavelength monopoles. The profile of the L-probe fed circular patch can be reduced to 0.092 λ_0 by shorting the circular patch to the ground plane by four copper wires [7]. The radius of this patch is also reduced due to the presence of shorting wires. The bandwidth can further be enhanced by connecting four trapezoidal plates orthogonally to the circular patch which is shorted to the ground plane by four copper wires [8]. A rectangular planar monopole with a bevel can further increase the impedance bandwidth. Nevertheless, owing to the asymmetry of the planar structure, its radiation patterns in the azimuth plane do not keep omnidirectional as the operating frequency increases [9]. A disk-loaded monopole reduces the profile to 0.08 λ_0. A monopole can also be created by connecting six triangle plates together. The regular hexagon is shorted to the ground plane by six wires [10]. The height of such an antenna is equal to 0.1 λ_0 at resonance frequency. Another type of monopolar patch is the sleeve monopole antenna [11]. This antenna is composed of a circular patch and a disc-conical sleeve, both of which are shorted to the ground plane through four shorting probes. The antenna has a low profile of 0.1 times the free space wavelength of the centre operating frequency. A circular sleeve structure can be added to improve the matching condition of the upper operating frequency edge and thus enhance the bandwidth [12].

The bandwidth enhancement for monopolar patch antennas were demonstrated [3] - [13] with/ without shorting wires. All these antennas have a profile of about 0.1 λ_0 (or even higher); nonetheless it is too thick for some applications such as the installation to an aircraft. Besides these antennas adopt an air substrate and their structures are not simple to be fabricated. A centre-fed circular microstrip patch with a coupled annular ring provides monopole-like radiation pattern [14]. Such antennas have low profile of 0.04 λ_0.

III. Antenna Design

In this paper we proposed a monopolar patch antenna. A step slotted antenna is designed. The parameters of the designed antenna are shown in Table no. 1. The antenna is printed on FR4 substrate with dielectric constant 4.4 and thickness 1.6 mm.

Table 1 : Dimensions of Slotted Step MSA

Antenna Parameter	Specification
Ground size	38.5 mm X 5 mm
Substrate size	38.5 mm X 44 mm
Patch steps	
W_p X S_1	28 mm X 12 mm
W_1 X S_2	24 mm X 5.75 mm
W_2 X S_3	12 mm X 5.25 mm
W_3 X S_4	8 mm X 5.75mm
Ground slot	6 mm X 3 mm
Feed Line Width	2.8 mm

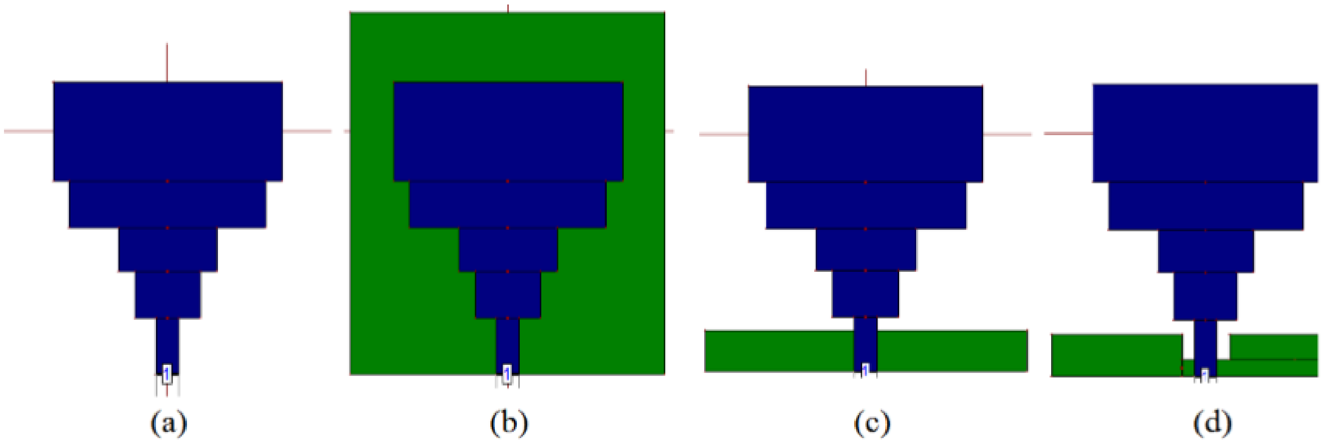

Fig. 1 : Geometry of designed antenna (a) with infinite ground plane, (b) with finite ground plane, (c) with defected ground structure 1 and (d) with defected ground structure 2 (final prototype)

Table 2 : Comparison of output parameters of designed prototype

Parameters	Infinite ground plane (Fig.1.a)	Finite ground plane (Fig.1.b)	Defected ground structure 1 (Fig.1.c.)		Defected ground structure 2 (Fig.1.d)		
Resonant Frequency	5.156 GHz	4.69 GHz	4.124 GHz	5.204 GHz	3.836 GHz	5.18 GHz	6.644 GHz
Return Loss	-15.136 dB	-29.56 dB	-22 dB	-25 dB	-15 dB	-24 dB	-18.1 dB
Bandwidth	1.396%	12.15%	18.523%		18.902%		
Gain	4.75 dBi	5.22 dBi	5.23 dBi		8.66 dBi		
Directivity	7.346 dBi	8.48 dBi	7.823 dBi		11.586 dBi		

Table 3 : Comparision of fabricated antenna with previously designed antenna

Parameter	Circular patch with annular ring [14]	Concentrically shorted circular patch [15]	Rectangular patch with periodic vias [16]	New low profile monopolar patch antenna
Principle	Slots on patch	Periodic shorting vias	Periodic shorting vias	Step slotted MSA and defected ground structure (DGS)
Substrate	Duroid 6002	Duroid 5870	Duroid 5870	FR4
Dimension	Diameter = 150 mm	Diameter = 180 mm	62.4 x 30.4 mm	44 x 38.5 mm
Profile	0.029λ	0.024λ	0.030λ	0.028λ
Resonance	5.8 GHz	2.4 GHz	5.8 GHz	3.836, 5.18 and 6.644 GHz
Bandwidth	12.8%	18%	12.48%	18.902%
Gain	5.7 dBi	6 dBi	9 dBi	8.66 dBi

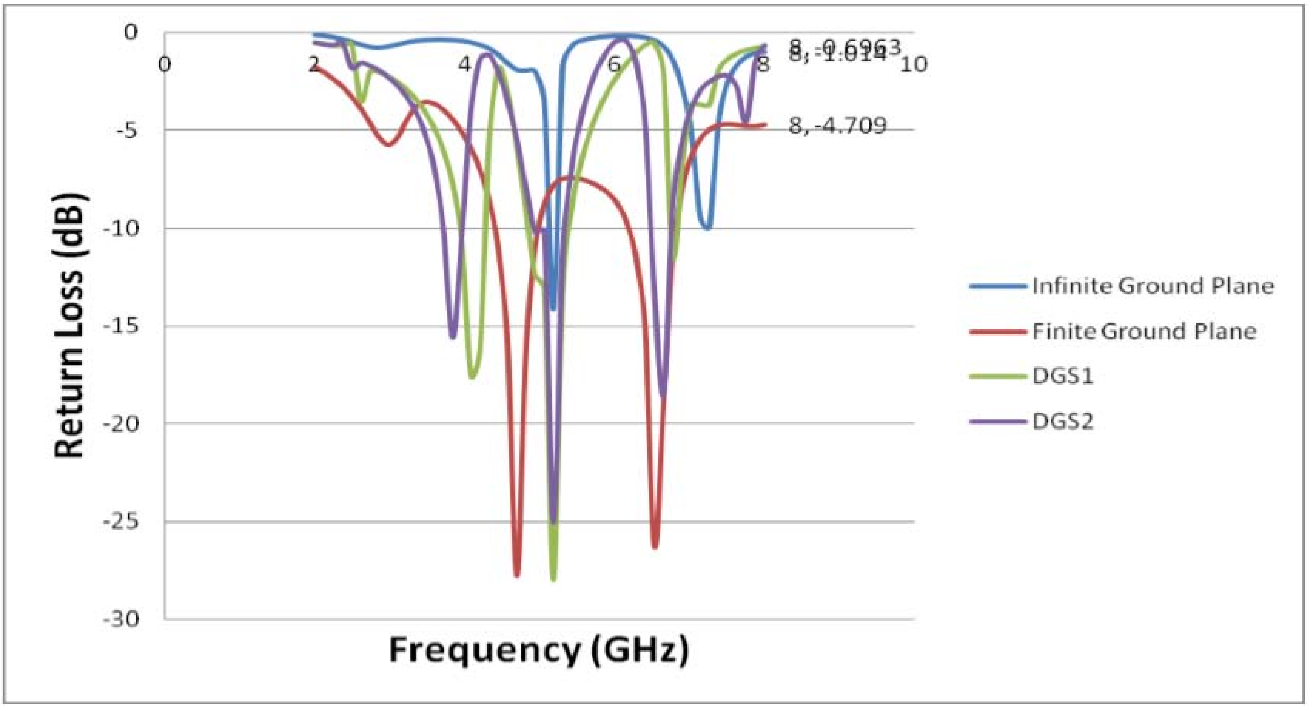

Fig. 2 : Comparison of return loss for the designed prototypes

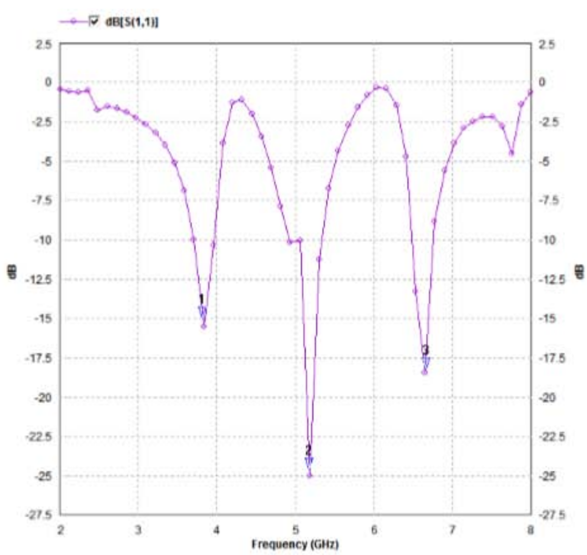

Fig. 3 : Return loss of proposed antenna with defected

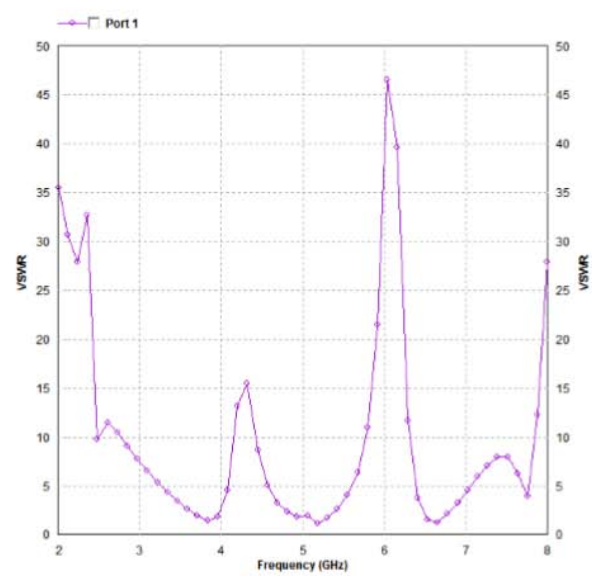

Fig. 4 : VSWR of proposed antenna with defected ground plane

The basis of the proposed antenna structure is a rectangular patch monopole, which has dimensions of length L and width W, and connected at the end of the CPW feed-line. The simulations were performed using IE3D software, a commercial full wave simulator based on Method of Moments (MOM).

IV. Results and Discussions

The dimensions for the prototype are finalized using iterative method. The designed monopolar patch has a profile of 0.027λ0 which is lower than that of a centre-fed monopolar patch [14]. The patch was initially simulated for an infinite ground plane. The antenna resonates at 5.156 GHz. Bandwidth of 1.396%, gain of 4.75 dBi and directivity of 7.346 dBi is obtained.

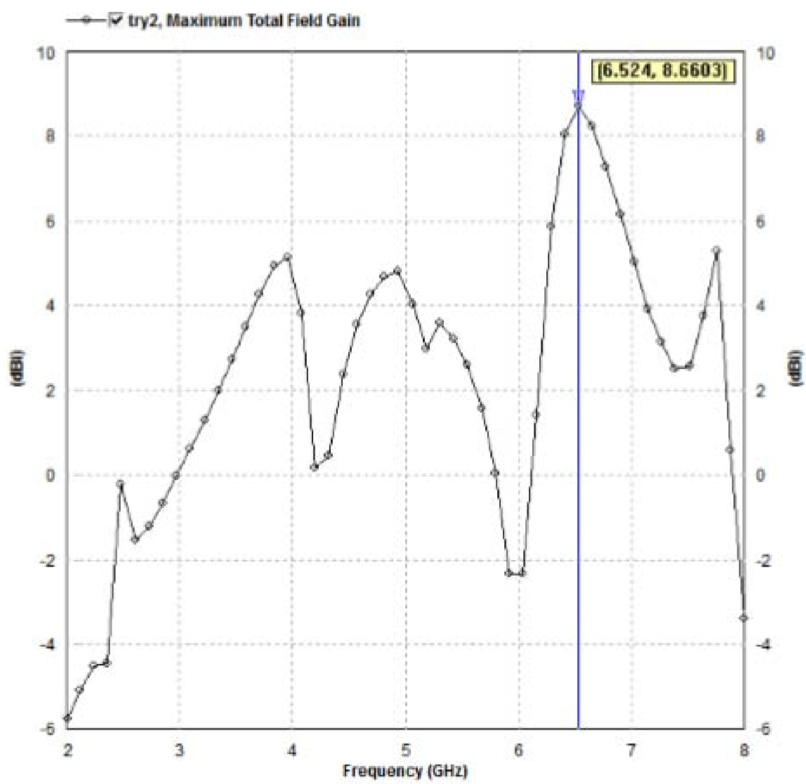

Fig. 5 : Gain of proposed antenna with defected ground plane

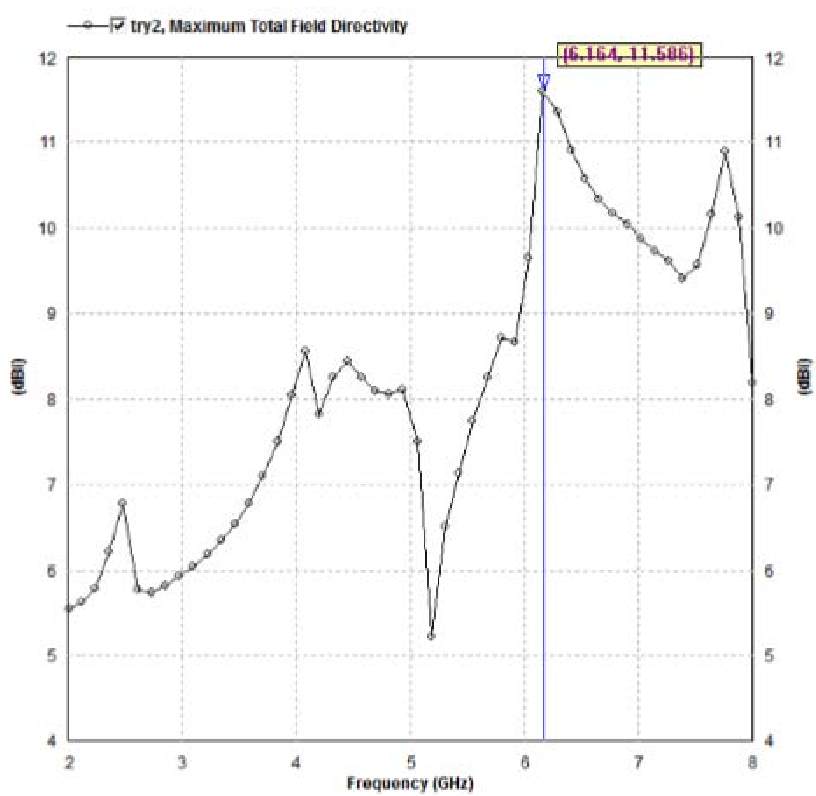

Fig. 6 : Directivity of proposed antenna with defected ground plane

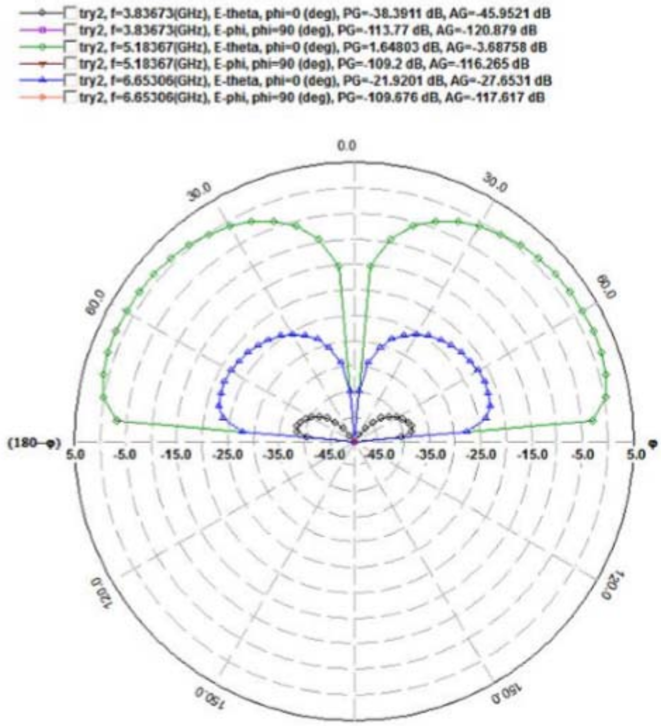

Fig. 7 : Elevation pattern of proposed antenna with defected ground plane

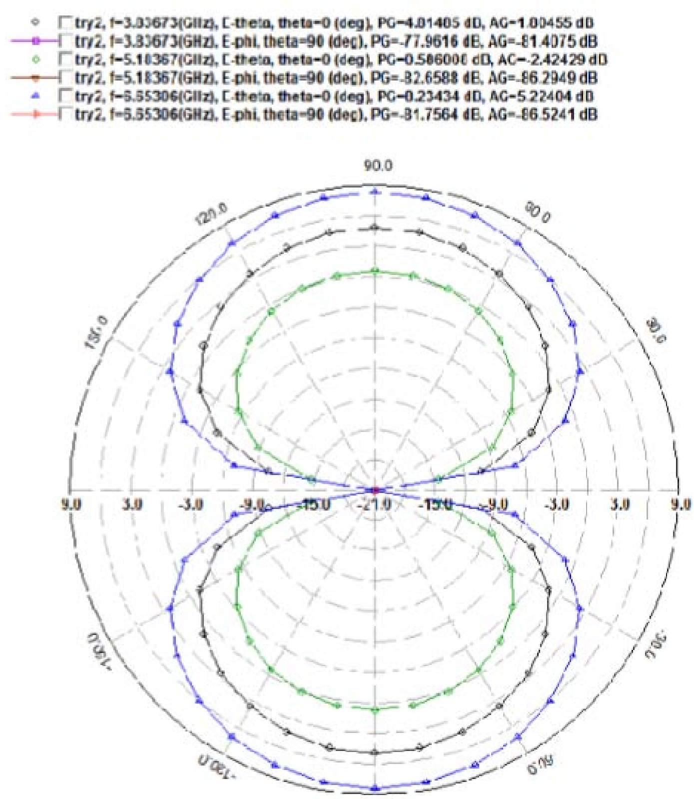

Fig. 8 : Azimuth pattern of proposed antenna with defected ground plane

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The antenna is simulated for finite ground plane, resonant frequency of 4.69 GHz is obtained, other parameters obtained are mentioned in table no. 2.Defected ground structure is used to increase the number of resonant frequencies and the bandwidth of the antenna. The parameters are shown in table 2. The return loss of the final prototype with DGS is shown in figure 2. Total bandwidth of 18.902% is obtained for the designed antenna. The comparative graph of return loss for all the four conditions is shown in figure 3. The VSWR plot for the final prototype is shown in figure 4. The VSWR is well below 2 for all the resonant bands. High gain of 8.66 dBi is obtained as depicted in figure 5. Figure 6 shows the directivity of the designed antenna. Directivity of 11.586 dBi is obtained as shown in figure 6. The cross polar and co-polar components of the elevation radiation pattern for all the resonant frequencies is shown in figure 7. The azimuth pattern is shown in figure 8. The three dimensional radiation pattern of the designed antenna at the resonant frequencies is shown in figure 9. The performance of the proposed antenna with that of the previously designed antenna is compared in table 3.

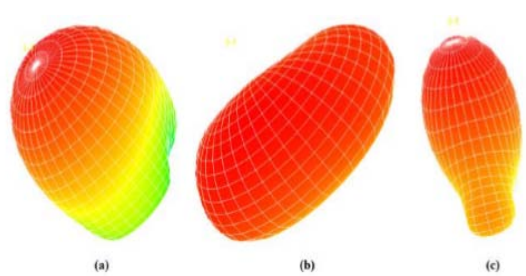

Fig. 9 : Radiation Pattern of Designed Antenna At (A) 3.836 Ghz, (B) 5.18 Ghz and (C) 6.644 Ghz

V. Conclusions

A broadband monopole antenna using step slotted microstrip patch has been designed. The design is improvised using defected ground structure (DGS). By the use of DGS we obtain higher number of resonant frequencies, high gain, high directivity and high bandwidth at a low profile. The antenna has been proposed, designed and simulated for WLAN operations. The simulated results show a bandwidth of 18.9%, gain of 8.66 dBi and monopole like radiation pattern at a low profile of 0.028 λ_0.

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Selecting and Redesigning Distribution Feeders for CVR Benefits

By Kaveh Rahimi, Himanshu Jain, Abhineet Parchure, Tamer Rousan & Robert Broadwater

Virginia Polytechnic Institute and State University, United States

Abstract- Conservation Voltage Reduction (CVR) is employed for peak load reduction and energy savings by electric utilities. Selecting feeders where the most benefit is realized from CVR is of interest. In the work here the theoretical CVR performance of over 1000 distribution feeders is evaluated based on circuit models and available load data. The feeders with the best CVR performance are identified, and characteristics of the efficient performing feeders are described. In identifying efficient performing feeders, load-voltage dependency factors for summer and winter are used in quasi-steady state power flow analysis. In addition, the Volt/VAR Control (VVC) scheme of a feeder with poor CVR performance is redesigned to improve its CVR performance. Results show that there can be considerable energy savings from investments in control schemes to improve CVR performance.

IndexTerms: *energy conservation, conservation voltage reduction, power distribution, scada systems, volt/VAR control*

GJRE-F Classification : *FOR Code: 090699*

SELECTINGAND REDESIGNINGDISTRIBUTIONFEEDERSFORCVRBENEFITS

Selecting and Redesigning Distribution Feeders for CVR Benefits

Kaveh Rahimi [α], Himanshu Jain [σ], Abhineet Parchure [ρ], Tamer Rousan [ω] & Robert Broadwater[§]

Abstract- Conservation Voltage Reduction (CVR) is employed for peak load reduction and energy savings by electric utilities. Selecting feeders where the most benefit is realized from CVR is of interest. In the work here the theoretical CVR performance of over 1000 distribution feeders is evaluated based on circuit models and available load data. The feeders with the best CVR performance are identified, and characteristics of the efficient performing feeders are described. In identifying efficient performing feeders, load-voltage dependency factors for summer and winter are used in quasi-steady state power flow analysis. In addition, the Volt/VAR Control (VVC) scheme of a feeder with poor CVR performance is redesigned to improve its CVR performance. Results show that there can be considerable energy savings from investments in control schemes to improve CVR performance.

Index Terms: energy conservation, conservation voltage reduction, power distribution, scada systems, volt/VAR control

I. Introduction

Conservation Voltage Reduction (CVR) has been used as a cost-effective method for obtaining energy savings, peak demand reduction, and feeder loss reduction [1]-[3]. The main objective of CVR is to reduce the real power consumed by loads. If loads are voltage dependent, this goal is achieved by lowering customer utilization voltage. However, the voltage needs to remain within allowed ranges established by regulatory agencies and standards [4], [5].

One of the first CVR tests was reported by American Electric Power System (AEP) in 1973 [6]. Since then many electric utilities have tested CVR and reported peak reduction and energy savings, including the Bonneville Power Administration (BPA) [7], Northeast Utilities (NU) [8], BC Hydro [9], Hydro Quebec (HQ) [10], and Dominion Virginia Power [11]. These investigations report savings ranging from 0.3% to 1% reduction in energy per 1% voltage reduction [12]. Considering CVR implementation nationwide, significant economic and environmental benefits may be obtained.

Peak demand and energy consumption reduction plus a decrease in feeder losses are benefits of CVR. However, investments in CVR result in reduced revenue for utilities. Incentives from regulatory agencies are required that can compensate for the lost revenue and utility investments in CVR implementation.

For open-loop loads CVR can be effective for reduction in energy consumption. Examples of open-loop loads include lighting loads and unregulated motors [3], [13], [14]. However, it has been shown that CVR may not be effective for closed loop loads such as motor drives, loads with thermal cycles and regulated constant power loads [3], [12], [14]. A closed-loop load is a load that has feedback control that compensates for the reduction in voltage. The voltage dependency of loads is very important when considering CVR.

The effect of voltage reduction on energy consumption is quantified using the Conservation Voltage Regulation Factor (CVRF) metric which is defined as:

$$CVRF = \frac{Percentage\ change\ in\ energy}{Percentage\ change\ in\ voltage} \qquad (1)$$

The larger the CVRF, the more the energy savings per percent reduction in voltage. Therefore, CVRF provides a metric for choosing loads or feeders that are good CVR performers. For feeders CVRF is time-dependent and is generally not easy to measure.

There are two major methods used for measuring CVRF on feeders. The first method is the comparison method. It has been implemented with two approaches. In the first approach two feeders with similar loading are selected. CVR is applied to one of the feeders while normal voltage operations is used for the other feeder. The resulting energy consumptions of the two feeders are then compared. In the second approach for determining feeder CVRF, CVR and normal operation voltages are applied to the same feeder during two different time periods, where the two different time periods have similar weather and loading conditions. The difference in feeder energy consumption between the two time periods can then be used to estimate the CVRF [15], [16]. However, since CVR is time and season dependent, the comparison measurements need to be performed a number of times.

When results from a number of field measurements are available, regression can be used in CVRF modeling. Using regression, the energy

Author α σ ρ: ECE Department, Virginia Tech Virginia, USA.
e-mails: k.rahimi@gmail.com, krahimi@ieee.org, jhim86@vt.edu, abhineet@vt.edu
Author ω: ECE Department, University of Illinois at Urbana-Champaign Illinois, USA. e-mail: trousan2@illinois.edu
Author §: Electrical Distribution Design (EDD) Virginia, USA.

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dependency can be modeled as a function of voltage, temperature, and other variables [9], [17]-[21] as indicated in (2).

$$E = f\ (T, V, \ldots) \tag{2}$$

Then CVRF can be computed as (1).

Previous CVR studies have mainly focused on the evaluation of energy savings [6]-[12], CVRF computation [15][21], or considering CVR as one of the objectives in an optimization problem [22]-[23]. However, few studies have assessed the characteristics of efficient distribution feeders for CVR Implementation.

When looking where to begin a CVR pilot or program, selection of distribution feeders with efficient CVR performance is of interest. Feeders with the best CVR performance would provide more return on investment. In the work reported here the CVR performance of approximately 1100 distribution feeders was compared. The comparison used measured winter and summer CVRF factors for two categories of feeders, urban and urban-rural. From the comparison 11 feeders with the best performance were selected. Characteristics of these 11 feeders that lead to the good CVR performance were evaluated. Also in the work reported here a feeder with poor CVR performance was chosen and its VVC scheme was redesigned.

Studying the characteristics of feeders with efficient CVR performance and investigating controls that can change a feeder with poor CVR performance into a good CVR performer are the main objectives of this work. The paper is organized as follows. Section II briefly discusses the major VVC methods. In section III the results of comparing the CVR performance of approximately 1100 feeders are presented and the characteristics of top CVR performers are discussed. In Section IV the control for a poor CVR performing feeder is redesigned, and the improvement obtained in the CVR performance is evaluated. Conclusions are presented in section V.

II. Volt/var Control

Maintaining acceptable utilization voltage levels and close to unity power factor are major objectives of VVC [24]. VVC has been used to reduce losses, energy consumption, power demand, and tear and wear on control devices. Typically, switched capacitor banks, substation load tap changing transformers (LTCs) and voltage regulators are the devices employed to perform VVC. However, smart grid initiatives have increased interest in more advanced VVC schemes. An efficient VVC system needs to meet the following criteria [14].

- Provides optimal coordinated control
- Provides user selectable operating objectives
- Performs self-monitoring
- Allows operator override during emergencies
- Adapts to feeder reconfiguration correctly.

Major VVC approaches that may be used by electric utilities are standalone VVC (traditional), SCADA driven Volt/VAR control, and Integrated Volt/VAR control (IVVC). The advantages and disadvantages of each of these approaches are discussed next.

Standalone VVC

In the standalone or traditional VVC, voltage regulation and reactive power control are performed by capacitors banks, LTCs or voltage regulators. Local voltage or current measurements determine the control actions. Low cost, scalability, and no need for field communications are advantages of the traditional VVC. On the other hand, standalone VVC cannot provide self-monitoring, coordination between control devices, optimal operation, and effective control with a high penetration of distributed generation [2].

SCADA Controlled Volt/VAR

With SCADA controlled Volt/VAR, control devices are equipped with communication capabilities through Supervisory Control and Data Acquisition (SCADA) systems. SCADA controlled Volt/VAR has been the most common VVC approach in the last 15 years [24]. Communication and coordination between controlling devices are the key points in SCADA controlled Volt/VAR. However, the control strategies are based on pre-defined rules which are determined by distribution system design engineers. SCADA controlled Volt/VAR usually consists of two separate subsystems which are VAR dispatch and voltage control. The VAR dispatch subsystem controls the capacitor banks to minimize feeder losses. The voltage control subsystem manages the LTCs and voltage regulators for minimizing the demand and energy consumption.

Higher efficiency, self-monitoring capability, and the ability to override operation during system emergencies are the advantages of the SCADA controlled Volt/VAR approach. However, it is less scalable and more complicated in comparison to traditional VVC. It does not adapt to feeder configuration changes and high distributed generation penetration. Furthermore, the VAR dispatch and voltage control subsystems are not usually coordinated and the system does not generally perform optimally [2].

Integrated Volt/VAR Control

The objective of IVVC is to determine the best (optimal) set of control actions. It determines the operation of LTCs, voltage regulators, capacitor banks and other control devices to achieve objectives in an optimal fashion while not violating operating constraints [25]-[27]. Optimal objectives may involve some combination of the following

- Minimizing losses
- Minimizing energy consumption
- Minimizing demand
- Minimizing voltage unbalance

- Minimizing control device actions

In IVVC an optimization problem is solved for control actions that provide optimal operating conditions. The computed set of control actions is sent to field control devices through the SCADA system. Voltage control and VAR dispatch are both coordinated in IVVC. IVVC can deal with complex feeder arrangements and reconfigurations. Finally,

Table 1 : Characteristics and Saving of the Selected Feeders for CVR Implementation

Feeder Name	Type	Annual MWh (Base Case)	Annual MWh with CVR (Coordinated Control)	Percentage Improvement	Saving (MWh)	Feeder Length (Mile)	Control Category
1	Urban-Rural	23728	22609	4.72%	1119	18.4	VVC Devices
2	Urban-Rural	23885	22794	4.57%	1091	22.9	VVC Devices
3	Urban	20567	19493	5.22%	1074	13.5	Flat VP
4	Urban	18336	17350	5.38%	986	9.4	Flat VP
5	Urban	18668	17690	5.24%	977	9.4	Flat VP
6	Urban-Rural	20245	19291	4.71%	954	11.1	VVC Devices
7	Urban	17931	16979	5.31%	953	14.5	Flat VP
8	Urban-Rural	20365	19433	4.58%	932	18.7	VVC Devices
9	Urban-Rural	17402	16614	4.53%	788	15.6	Flat VP
10	Urban-Rural	14279	13615	4.65%	664	13.0	Flat VP
11	Urban-Rural	13498	12840	4.87%	658	4.1	Flat VP

IVVC can handle high penetrations of distributed generation. On other hand, IVVC implementations may not be scalable, and the implementation can be costly [14].

III. Characteristics of the Best CVR Performers

Using experimentally determined summer and winter CVRFs, the CVR performance of approximately 1100 urban and urban-rural distribution feeders under a VVC scheme was evaluated. The energy savings for each feeder were computed, and the eleven feeders that had the best CVR performance were selected. Power flow calculations based on SCADA measurements were used in the evaluations of the eleven feeders, where the power flow calculations were run for each hour of a year, 8760 times, for each feeder to calculate energy supplied and feeder losses. Table I shows the best CVR performers' estimated annual energy savings, energy consumption reduction, length and category.

Studying the topology and voltage profiles of the best performers, it is observed that a good performer has a flat voltage profile due to either the topology/loading conditions or sufficient Volt/VAR control devices to create a flat voltage profile. Fig. 1 shows a relatively flat voltage profile, in terms of customer level voltage, for a top CVR performing feeder at peak load (Feeder 9 in Table 1 - a short feeder without VVC). The percentage voltage deviation versus distance from the substation is also illustrated for Feeder 9. The voltage drop for Feeder 9 is approximately 1.7V from an initial 125V at the substation.

Fig. 2 presents the voltage drop for an efficient CVR performer with VVC devices, Feeder 2. It can be seen that the voltage level is boosted 4 times by regulators. Fig. 2 also shows the percent voltage deviation versus distance for Feeder 2. As shown in Table I, Feeder 2 was the second top CVR performer in terms of energy savings. Fig. 3 shows results for Feeder 8, a relatively short feeder with VVC. The effect of the capacitor banks on Feeder 8 can be seen around 1.9 miles from the substation. It should be noted that Figs 1-3 are plotted for the phase which has the least voltage at the end of the feeder.

A scatter plot of feeder annual MWh consumption versus annual MWh savings is plotted in Fig. 4 for the eleven top CVR

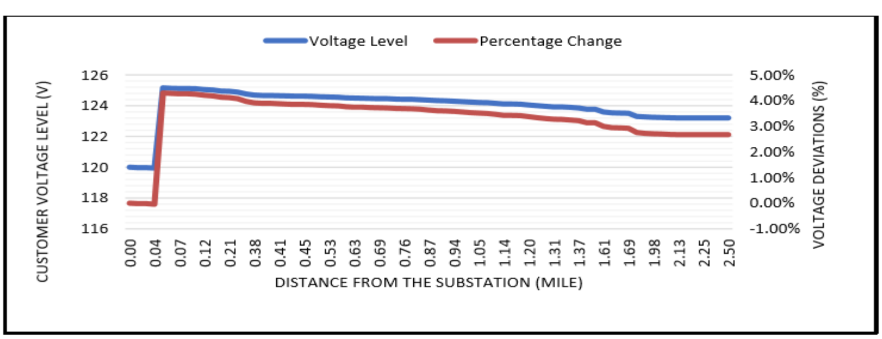

Figure 1 : Voltage Drop Versus Distance for Feeder 9, A Short Feeder Without VVC Devices

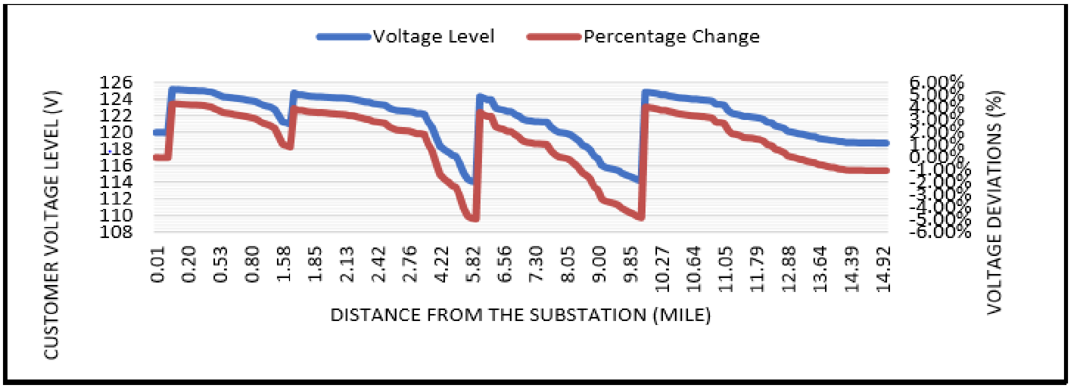

Figure 2 : Voltage drop versus distance for Feeder 2 with VVC devices

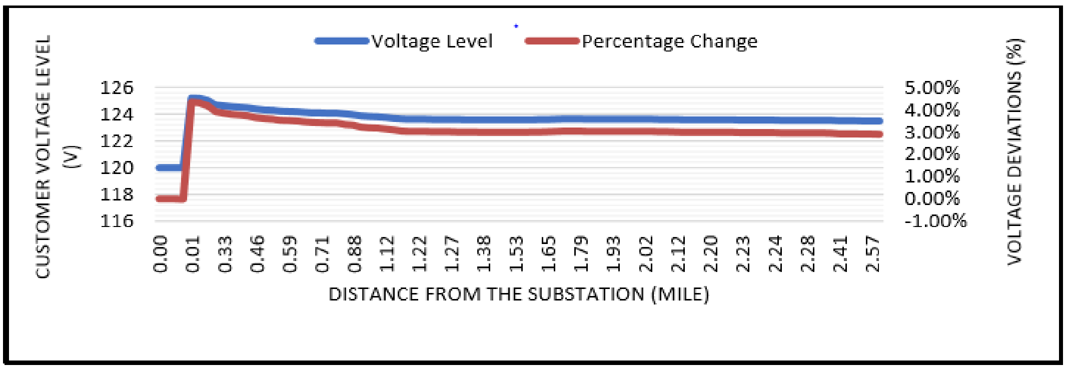

Figure 3 : Voltage drop versus distance for Feeder 8, a feeder with VVC devices and a relatively flat voltage profile

performing feeders. When the top CVR performing feeders are categorized according to their characteristics, a natural flat voltage profile or VVC devices, a more precise correlation is found among the feeders. This is illustrated in figs 5 and 6, where the R2 correlation criterion increases from 0.848 in Fig. 4 to 0.919 and 0.898 for figs 5 and 6, respectively. In addition, figs 5 and 6 illustrate that when a selection is to be made as to whether CVR should be implemented on one feeder or another, where both feeders have a flat voltage profile, the feeder with the higher energy consumption can provide more energy and thus dollar savings.

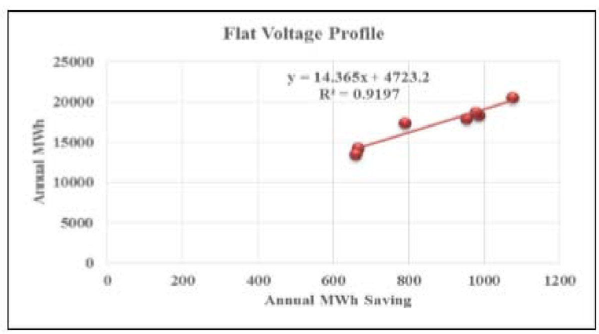

Figure 5 : Correlation between annual MWh savings and MWh consumption for top CVR performing feeders with relatively flat voltage profiles

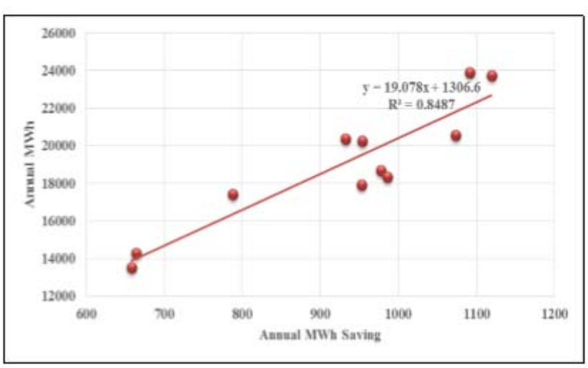

Figure 4 : Correlation between annual saving and feeder annual consumption for the eleven top CVR performing feeders

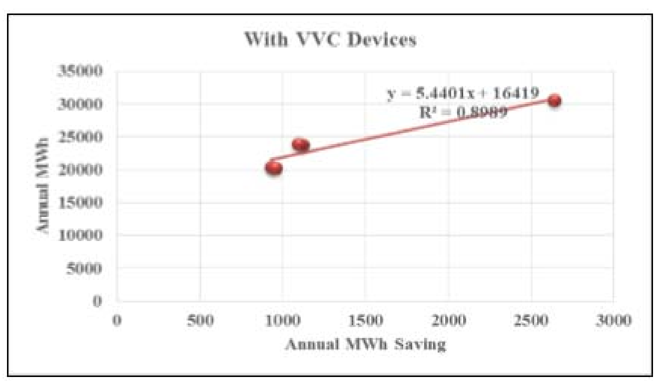

Figure 6 : Correlation between annual MWh savings and annual MWh consumption for top CVR performing

IV. Modifying a Poor Cvr Performer into a Top Perfomer

In this section, a poor CVR performing feeder is chosen and its VVC scheme is redesigned. The goal is to create a flatter voltage profile to achieve better CVR performance. Voltage dependency factors of -0.1 and -0.6, as defined by equation 1, were employed for summer and winter, respectively.

The selected feeder originally had two voltage regulators (one at the substation), four 3-phase fixed capacitors, and one 3-phase switched capacitor, where the capacitors all together represented 3450 kVAR. The existing standards require the utilization voltage to be between 114 and 126 V. The goal for the redesigned VVC is to maintain the primary system voltage, in terms of customer level voltage, to be greater than 116 V. This would allow for a 2 volt drop in the secondary. Figs 7 and 8 show the percent voltage drop before and after redesigning the VVC system and applying the CVR control for summer and winter conditions, respectively.

Nine single-phase, small switched capacitors were employed in the new VVC scheme, representing a total of 1500 kVAR, which is less than half of the original VAR support. Discrete Ascent Optimal Programming (DAOP) was employed to place the switched capacitors [28]. Table II presents the capacitor types and kVARs employed in the feeder before and after redesigning the VCC scheme. The new VVC system improved the voltage profile such that CVR can be implemented with 120V at the substation and 118 V at the second regulator. In summer, the maximum voltage drop before the redesign was approximately 2.5%. The maximum voltage drop after the VVC redesign was 1.5% and after CVR implementation was about 3.5%. In winter, before redesigning the VVC system, the maximum percent voltage drop was about 2%. However, after redesigning the VVC scheme, the maximum percent voltage drop was approximately 1% and after CVR implementation was about 3%. Since the percent voltage drop requirement was 5% or less, additional CVR savings could be obtained by reducing the regulator set-points even further. The configuration of the feeder's VVC devices before and after the VVC scheme redesign is shown in figs 9a and 9b, respectively.

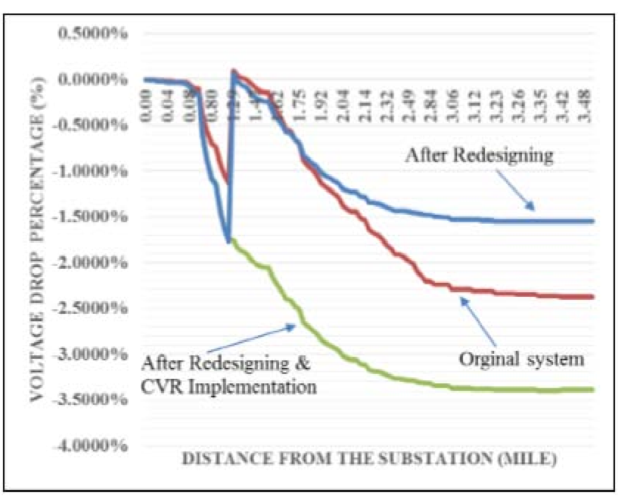

Figure 7 : Percent voltage drop before and after redesigning the VVC system for the selected poor performing feeder during summer

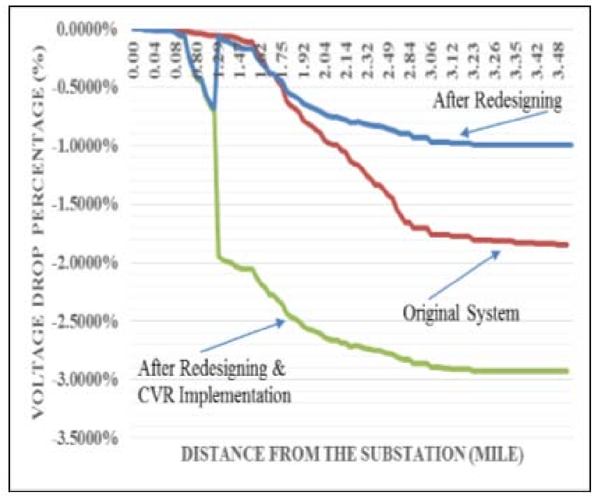

Figure 8 : Percent voltage drop before and after redesigning the VVC system for the selected poor performing feeder during winter

Table III presents the characteristics of the selected poor CVR performing feeder before and after the VVC redesign. Annual consumption before redesigning the VVC system was 27130 MWh. After the VVC redesign the annual consumption decreased to 26148 MWh, which provided a savings of 983 MWh per year. This corresponds to a 3.63% increase in energy savings. Note that the modified poor performing feeder now ranks in the top five performing feeders shown in Table I.

This VVC redesign case study shows that employing many VVC devices is not a necessary condition for reasonable CVR performance of a feeder. While VVC devices can help in improving the voltage profile, efficient design of the VVC scheme and consideration of CVR implementation in its design can significantly improve the CVR performance of a feeder. Moreover, the significant decrease in VAR support (more than 50% decrease) showed the effect of distributing VVC devices in improving the CVR performance.

V. Conclusion

When considering CVR implementation across a large number of feeders, selecting the best CVR performing feeders is of interest. Initially investing in the best CVR performers will provide the greatest benefits from the investment. This work evaluated over 1100 distribution feeders using their seasonal CVRFs and

Table 2 : VVC Devices Before and After Redesign

Before		
Phase	**Capacitor Type**	**Capacity (kVAR)**
3 (ABC)	Fixed	1200
3 (ABC)	Fixed	900
3 (ABC)	Fixed	600
3 (ABC)	Fixed	450
3 (ABC)	Switched	300
	Total	3450
After		
Phase	**Capacitor Type**	**Capacity (kVAR)**
1 (A)	Switched	200
1 (A)	Switched	200
1 (A)	Switched	100
1 (A)	Switched	150
1 (B)	Switched	200
1 (B)	Switched	200
1 (B)	Switched	200
1 (C)	Switched	150
1 (C)	Switched	100
	Total	1500

Table 3 : Characteristics and Saving of the Modified Feeder After Cvr Implementation

Feeder Name	Type	Annual MWh (Base Case)	Annual MWh with CVR (Coordinated Control)	Percentage Improvement	Saving (MWh)	Feeder Length (Mile)	Control Category
12	Urban-Rural	27130	26148	3.62%	983	25.2	VVC Devices

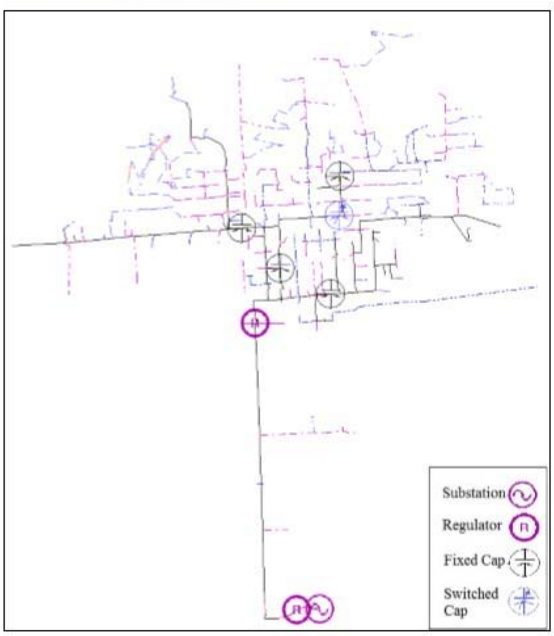

Figure 9 a. Placemen of control devices for selected poor CVR Performing feeder before redesigning the VVC scheme

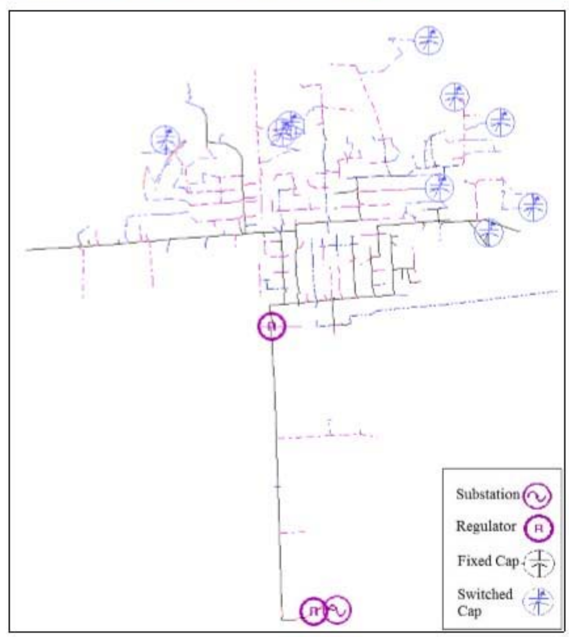

Figure 9 b. Placemen of control devices for selected poor CVR Performing feeder after redesigning the VVC scheme

computed energy saving under a CVR scheme. After selecting the best CVR performers, their characteristics, as well as their energy savings, were identified. It was observed that efficient CVR performers had a relative flat voltage profile due to either topology/loading patterns or sufficient VVC devices.

A feeder with poor CVR performance was chosen and its VVC scheme redesigned. After redesigning the VVC scheme, the poor CVR performer changed into one of the top CVR performing feeders, providing a significant increase in CVR energy savings. This case study also illustrated that significant decrease in VAR support could be obtained when a distributed VVC scheme was utilized. Future work needs to address integration of intermittent renewable energy resources in a combined CVR and VVC scheme.

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Laws of the Electro-Electrical Induction

By F. F. Mende & A. S. Dubrovin
B.I. Verkin Institute, Ukraine

Abstract- The concept of scalar-vector potential, the assuming dependence of the scalar potential of charge and it pour on from the speed it made possible to explain a whole series of the phenomena, connected with the motion of charge, which earlier in the classical electrodynamics an explanation did not have. Such phenomena include the phase aberration of electromagnetic waves, the transverse Doppler effect, the phenomenon of Lorentz force. In this article the new law of electro-electrical induction, which explains nature of dipole emission, will be examined on the basis of the concept of scalar- vector potential.

Keywords: *maxwell equation, scalar-vector potential, dipole moment, dipole emission, ampere law, helmholtz theorem.*

GJRE-F Classification : *FOR Code: 240504p*

LAWS OFTHEELECTRO-ELECTRICALINDUCTION

Strictly as per the compliance and regulations of :

Laws of the Electro-Electrical Induction

F. F. Mende [α] & A. S. Dubrovin [σ]

Abstract- The concept of scalar-vector potential, the assuming dependence of the scalar potential of charge and it pour on from the speed it made possible to explain a whole series of the phenomena, connected with the motion of charge, which earlier in the classical electrodynamics an explanation did not have. Such phenomena include the phase aberration of electromagnetic waves, the transverse Doppler effect, the phenomenon of Lorentz force. In this article the new law of electro-electrical induction, which explains nature of dipole emission, will be examined on the basis of the concept of scalar- vector potential.

Keywords: maxwell equation, scalar-vector potential, dipole moment, dipole emission, ampere law, helmholtz theorem.

I. Introduction

Maxwell equations attest to the fact that in the free space the transverse electromagnetic waves can exist [1, 2]. Together with the boundary conditions these equations give the possibility to solve the problems of reflection and propagation of such waves in the locked and limited structures. With the aid of Maxwell equations it is possible to solve the problems of emission. But since the equations indicated are phenomenological, physics of such processes thus far remains not clear. Similar problems can be solved, also, with the use of potentials. This approach opens greater possibilities, but physics of the vector potential of magnetic field also up to now remained not clear. The development of the concept of scalar- vector potential, which dedicated a number of works [3-10], it made it possible to open the physical essence of a number of the fundamental laws of electrodynamics, charges connected with the motion. This concept assumes the dependence of the scalar potential of charge on its relative speed. It is obtained by the way of the symmetrization of the laws of induction with the use by the substantial derivative. This approach made possible to explain such phenomena as the phase aberration of electromagnetic waves, transverse Doppler effect, power interaction of the current carrying systems and nature of Lorentz force. In this article the new law of electro-electrical induction, which explains nature of dipole emission, will be examined on the basis of the concept of scalar-vector potential.

Author α σ: e-mails: mende_fedor@mail.ru, asd_kiziltash@mail.ru

II. Law of the Electro-Electrical Induction

In the works [3-10] is developed the concept of scalar vector potential, from which it follows that the scalar potential depends on speed. This dependence is determined by relationship.

$$\varphi(r,t)=\frac{g\ ch\frac{v_\perp}{c}}{4\pi\ \varepsilon_0 r},$$

where $v_\perp$ is component of the charge rate g, normal to

to vector $\vec{r}$, connecting charge with the observation point.

Since pour on any process of the propagation of electrical and potentials it is always connected with the delay, let us introduce the being late scalar- vector potential, by considering that the field of this potential is extended in this medium with a speed of light [1, 2]:

$$\varphi(r,t)=\frac{g\ ch\frac{v_\perp\left(t-\frac{r}{c}\right)}{c}}{4\pi\ \varepsilon_0 r} \tag{2.1}$$

where $v_\perp\left(t-\frac{r}{c}\right)$ is component of the charge rate of g, normal to

to the vector $\vec{r}$ at the moment of the time $t'=t-\frac{r}{c}$,

r is distance between the charge and the point, at which is determined the field, at the moment of the time t.

Using a relationship $\vec{E}=-grad\ \varphi(r,t)$, let us find field at point 1 (Fig. 1) The gradient of the numerical value of a radius of the vector of $\vec{r}$ is a scalar function of two points: the initial point of a radius of vector and its end point (in this case this point 1 on the axis of x and point 0 at the origin of coordinates).

Point 1 is the point of source, while point 0 - by observation point. With the determination of gradient from the function, which contains a radius depending on the conditions of task it is necessary to distinguish two cases:

1) the point of source is fixed and $\vec{r}$ is considered as the function of the position of observation point.

2) observation point is fixed and $\vec{r}$ is considered as the function of the position of the point of source.

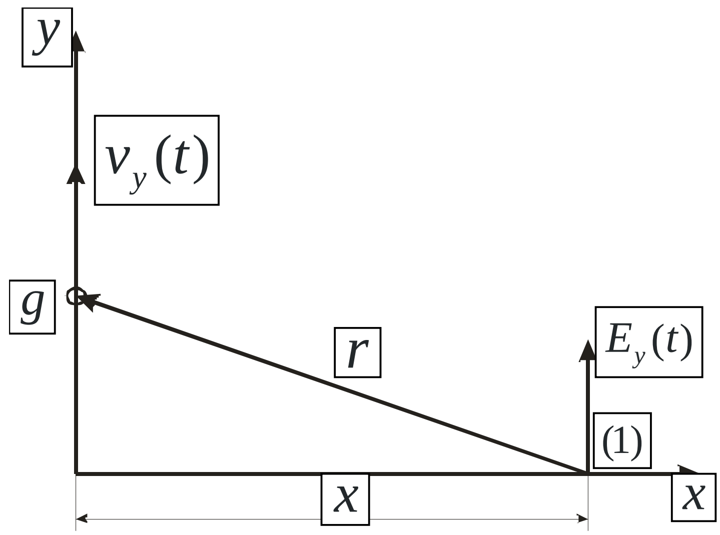

Fig. 1 : Diagram of shaping of the induced electric field.

We will consider that the charge of e accomplishes fluctuating motion along the axis of y, in the environment of point 0, which is observation point, and fixed point 1 is the point of source and $\vec{r}$ is considered as the function of the position of charge. Then we write down the value of electric field at point 1:

$$E_y(1) = -\frac{\partial\varphi_\perp(r,t)}{\partial y} = -\frac{\partial}{\partial y}\frac{e}{4\pi\varepsilon_0 r(y,t)}\,ch\frac{v_y\left(t-\frac{r(y,t)}{c}\right)}{c}$$

When the amplitude of the fluctuations of charge is considerably less than distance to the observation point, it is possible to consider a radius vector constant. We obtain with this condition:

$$E_y(x,t) = -\frac{e}{4\pi\varepsilon_0 cx}\frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial y}\,sh\frac{v_y\left(t-\frac{x}{c}\right)}{c} \qquad (2.2)$$

where x is some fixed point on the axis x.

Taking into account that

$$\frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial y} = \frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial t}\frac{\partial t}{\partial y} = \frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial t}\frac{1}{v_y\left(t-\frac{x}{c}\right)}$$

we obtain from (2.2)

$$E_y(x,t)=\frac{e}{4\pi\varepsilon_0 cx}\frac{1}{v_y\left(t-\frac{x}{c}\right)}\frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial t}sh\frac{v_y\left(t-\frac{x}{c}\right)}{c} \qquad (2.3)$$

This is a complete emission law of the moving charge.

If we take only first term of the expansion of $sh\frac{v_y\left(t-\frac{x}{c}\right)}{c}$, then we will obtain from (2.3):

$$E_y(x,t)=-\frac{e}{4\pi\varepsilon_0 c^2 x}\frac{\partial v_y\left(t-\frac{x}{c}\right)}{\partial t}=-\frac{ea_y\left(t-\frac{x}{c}\right)}{4\pi\varepsilon_0 c^2 x} \qquad (2.4)$$

where $a_y\left(t-\frac{x}{c}\right)$ is being late acceleration of charge. This relationship is wave equation and defines both the amplitude and phase responses of the wave of the electric field, radiated by the moving charge.

If we as the direction of emission take the vector, which lies at the plane xy, and which constitutes with the axis y the angle α, then relationship (2.4) takes the form:

$$E_y(x,t,\alpha)=-\frac{ea_y\left(t-\frac{x}{c}\right)\sin\alpha}{4\pi\varepsilon_0 c^2 x} \qquad (2.5)$$

The relationship (2.5) determines the radiation pattern. Since in this case there is axial symmetry relative to the axis y, it is possible to calculate the complete radiation pattern of this emission. This diagram corresponds to the radiation pattern of dipole emission.

Since $\frac{ev_z\left(t-\frac{x}{c}\right)}{4\pi x}=A_H\left(t-\frac{x}{c}\right)$ is being late vector potential, relationship (2.5) it is possible to rewrite

$$E_y(x,t,\alpha)=-\frac{ea_y\left(t-\frac{x}{c}\right)\sin\alpha}{4\pi\varepsilon_0 c^2 x}=-\frac{1}{\varepsilon_0 c^2}\frac{\partial A_H\left(t-\frac{x}{c}\right)}{\partial t}=$$

$$=-\mu_0\frac{\partial A_H\left(t-\frac{x}{c}\right)}{\partial t}$$

Is again obtained complete agreement with the equations of the being late vector potential, but vector potential is introduced here not by phenomenological method, but with the use of a concept of the being late scalar- vector potential. It is necessary to note one important circumstance: in Maxwell's equations the electric fields, which present wave, vortex. In this case the electric fields bear gradient nature.

Let us demonstrate the still one possibility, which opens relationship (2.5). Is known that in the electrodynamics there is this concept, as the electric dipole and the dipole emission, when the charges, which are varied in the electric dipole, emit electromagnetic waves. Two charges with the opposite signs have the dipole moment:

$$\vec{p} = e\vec{d} \quad (2.6)$$

where the vector $\vec{d}$ is directed from the negative charge toward the positive charge. Therefore current can be expressed through the derivative of dipole moment on the time

$$e\vec{v} = e\frac{\partial \vec{d}}{\partial t} = \frac{\partial \vec{p}}{\partial t}$$

Consequently

$$\vec{v} = \frac{1}{e}\frac{\partial \vec{p}}{\partial t},$$

and

$$\vec{a} = \frac{\partial \vec{v}}{\partial t} = \frac{1}{e}\frac{\partial^2 \vec{p}}{\partial t^2}.$$

Substituting this relationship into expression (2.5), we obtain the emission law of the being varied dipole.

$$\vec{E} = -\frac{1}{4\pi r\varepsilon_0 c^2}\frac{\partial^2 p(t-\frac{r}{c})}{\partial t^2}. \quad (2.7)$$

This is also very well known relationship [1].

In the process of fluctuating the electric dipole are created the electric fields of two forms. First, these are the electrical induction fields of emission, represented by equations (2.4), (2.5) and (2.6), connected with the acceleration of charge. In addition to this, around the being varied dipole are formed the electric fields of static dipole, which change in the time in connection with the fact that the distance between the charges it depends on time. Specifically, energy of these pour on the freely being varied dipole and it is expended on the emission. However, the summary value of field around this dipole at any moment of time defines as superposition pour on static dipole pour on emissions.

The laws (2.4), (2.5), (2.7) are the laws of the direct action, in which already there is neither magnetic pour on nor vector potentials. I.e. those structures, by which there were the magnetic field and magnetic vector potential, are already taken and they no longer were necessary to us.

Using relationship (2.5) it is possible to obtain the laws of reflection and scattering both for the single charges and, for any quantity of them. If any charge or group of charges undergo the action of external (strange) electric field, then such charges begin to accomplish a forced motion, and each of them emits electric fields in accordance with relationship (2.5). The superposition of electrical pour on, radiated by all charges, it is electrical wave.

If on the charge acts the electric field of, then the acceleration of charge is determined by the equation:

$$a = -\frac{e}{m}E'_{y0}\sin\omega t.$$

Taking into account this relationship (2.5) assumes the form

$$E_y(x,t,\alpha) = \frac{e^2\sin\alpha}{4\pi\varepsilon_0 c^2 mx}E'_{y0}\sin\omega(t-\frac{x}{c}) = \frac{K}{x}E'_{y0}\sin\omega(t-\frac{x}{c}), \quad (2.8)$$

where the coefficient $K = \frac{e^2\sin\alpha}{4\pi\varepsilon_0 c^2 m}$ can be named the coefficient of scattering (re-emission) single charge in the assigned direction, since it determines the ability of charge to re-emit the acting on it external electric field.

The current wave of the displacement accompanies the wave of electric field:

$$j_y(x,t) = \varepsilon_0\frac{\partial E_y}{\partial t} = -\frac{e\sin\alpha}{4\pi c^2 x}\frac{\partial^2 v_y\left(t-\frac{x}{c}\right)}{\partial t^2}.$$

If charge accomplishes its motion under the action of the electric field of, then bias current in the distant zone will be written down as

$$j_y(x,t) = -\frac{e^2\omega}{4\pi c^2 mx} E'_{y0} \cos\omega\left(t - \frac{x}{c}\right). \tag{2.9}$$

The sum wave, which presents the propagation of electrical pour on (2.8) and bias currents (2.9), can be named the electrocurent wave. In this current wave of displacement lags behind the wave of electric field to the angle equal $\frac{\pi}{2}$. For the first time this term and definition of this wave was used in the works [3, 4].

In parallel with the electrical waves it is possible to introduce magnetic waves, if we assume that

$$\vec{j} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} = rot\vec{H} \qquad (2.10),$$

$$div\vec{H} = 0.$$

Introduced thus magnetic field is vortex. Comparing (2.9) and (2.10) we obtain:

$$\frac{\partial H_z(x,t)}{\partial x} = \frac{e^2\omega \ \sin\alpha}{4\pi c^2 mx} E'_{y0} \cos\omega\left(t - \frac{x}{c}\right).$$

Integrating this relationship on the coordinate, we find the value of the magnetic field

$$H_z(x,t) = \frac{e^2 \ \sin\alpha}{4\pi cmx} E'_{y0} \sin\omega\left(t - \frac{x}{c}\right). \tag{2.11}$$

Thus, relationship (2.8), (2.9) and (2.11) can be named the laws of electrical-electrical induction, since. They give the direct coupling between the electric fields, applied to the charge, and by fields and by currents induced by this charge in its environment. Charge itself comes out in the role of the transformer, which ensures thisprozess. The magnetic field, which can be calculated with the aid of relationship (2.11), is directed normally both toward the electric field and toward the direction of propagation, and their relation at each point of the space is equal:

$$\frac{E_y(x,t)}{H_z(x,t)} = \frac{1}{\varepsilon_0 c} = \sqrt{\frac{\mu_0}{\varepsilon_0}} = Z,$$

where Z is wave drag of free space.

Wave drag determines the active power of losses on the single area, located normal to the direction of propagation of the wave:

$$P = \frac{1}{2} Z E^2_{y0}.$$

Therefore electrocurentwave, crossing this area, transfers through it the power, determined by the data by relationship, which is located in accordance with Poynting theorem about the power flux of electromagnetic wave. Therefore, for finding all parameters, which characterize wave process, it is sufficient examination only of electrocurentwave and knowledge of the wave drag of space. In this case it is in no way compulsory to introduce this concept as magnetic field and its vector potential, although there is nothing illegal in this. In this setting of the relationships, obtained for the electrical and magnetic field, they completely satisfy Helmholtz's theorem. This theorem says, that any single-valued and continuous vectorialfield $\vec{F}$, which turns into zero at infinity, can be represented uniquely as the sum of the gradient of a certain scalar function φ and rotor of a certain vector function $\vec{C}$, whose divergence is equal to zero:

$$\vec{F} = grad\varphi + rot\vec{C},$$

$$div\vec{C} = 0.$$

Consequently, must exist clear separation pour on to the gradient and the vortex. It is evident that in the expressions, obtained for those induced pour on, this separation is located. Electric fields bear gradient nature, and magnetic is vortex.

Thus, the construction of electrodynamics should have been begun from the acknowledgement of the dependence of scalar potential on the speed. But nature very deeply hides its secrets, and in order to come to this simple conclusion, it was necessary to pass way by length almost into two centuries. The grit, which so harmoniously were erected around the magnet poles, in a straight manner indicated the presence of some power pour on potential nature, but to this they did not turn attention; therefore it turned out that all examined only tip of the iceberg, whose substantial part remained invisible of almost two hundred years.

Taking into account entire aforesaid one should assume that at the basis of the overwhelming majority of static and dynamic phenomena at the electrodynamics only one formula (2.1), which assumes the dependence of the scalar potential of charge on the speed, lies.

From this formula it follows and static interaction of charges, and laws of power interaction in the case of their mutual motion, and emission laws and scattering. This approach made it possible to explain from the positions of classical electrodynamics such phenomena as phase aberration and the transverse Doppler effect, which within the framework the classical electrodynamics of explanation did not find. After entire aforesaid it is possible to remove construction forests, such as magnetic field and magnetic vector potential, which do not allow here already almost two hundred years to see the building of electrodynamics in entire its sublimity and beauty.

Let us point out that one of the fundamental equations of induction (2.4) could be obtained directly from the Ampere law, still long before appeared Maxwell equations. The Ampere law, expressed in the vector form, determines magnetic field at the point x, y, z

$$\vec{H} = \frac{1}{4\pi}\int \frac{I d\vec{l} \times \vec{r}}{r^3}$$

where I is current in the element $d\vec{l}$, $\vec{r}$ is vector, directed from $d\vec{l}$ to the point x, y, z.

It is possible to show that

$$\frac{[d\vec{l}\vec{r}]}{r^3} = grad\left(\frac{1}{r}\right) \times d\vec{l}$$

and, besides the fact that

$$grad\left(\frac{1}{r}\right) \times d\vec{l} = rot\left(\frac{d\vec{l}}{r}\right) - \frac{1}{r} rot\ d\vec{l}.$$

but the rotor $d\vec{l}$ is equal to zero and therefore is final

$$\vec{H} = rot\int I\left(\frac{d\vec{l}}{4\pi r}\right) = rot\ \vec{A}_H$$

where

$$\vec{A}_H = \int I\left(\frac{d\vec{l}}{4\pi r}\right) \quad (2.12)$$

the remarkable property of this expression is that that the vector potential depends from the distance to the observation point as $\frac{1}{r}$. Specifically, this property makes it possible to obtain emission laws.

Since $I = gv$, where g the quantity of charges, which falls per unit of the length of conductor, from (2.12) we obtain:

$$\vec{A}_H = \int \frac{gv\ d\vec{l}}{4\pi r}.$$

For the single charge of e this relationship takes the form:

$$\vec{A}_H = \frac{e\vec{v}}{4\pi r},$$

and since

$$\vec{E} = -\mu\frac{\partial \vec{A}}{\partial t},$$

that

$$\vec{E} = -\mu\int \frac{g\frac{\partial v}{\partial t}\ d\vec{l}}{4\pi r} = -\mu\int \frac{ga\ d\vec{l}}{4\pi r}, \quad (2.13)$$

where a is acceleration of charge.

This relationship appears as follows for the single charge:

$$\vec{E} = -\frac{\mu e\vec{a}}{4\pi r}. \quad (2.14)$$

If we in relationships (2.13) and (2.14) consider that the potentials are extended with the final speed and to consider the delay of $\left(t - \frac{r}{c}\right)$, and assuming $\mu = \frac{1}{\varepsilon_0 c^2}$, these relationships will take the form:

$$\vec{E} = -\mu\int \frac{ga(t - \frac{r}{c})\ d\vec{l}}{4\pi r} = -\int \frac{ga(t - \frac{r}{c})\ d\vec{l}}{4\pi\varepsilon_0 c^2 r}, \quad (2.15)$$

$$\vec{E} = -\frac{e\vec{a}(t - \frac{r}{c})}{4\pi\varepsilon_0 c^2 r} \qquad (2.16)$$

The relationship (2.15) and (2.16) represent, it is as shown higher (see (2.4)), wave equations. Let us note that these equations - this solution of Maxwell's equations, but in this case they are obtained directly from the Ampere law, not at all coming running to Maxwell equations. To there remains only present the question, why electrodynamics in its time is not banal by this method.

Given examples show, as electrodynamics in the time of its existence little moved. The phenomenon of electromagnetic induction Faraday opened into 1831 and already almost 200 years its study underwent practically no changes, and the physical causes for the most elementary electrodynamic phenomena, until now, were misunderstood. Certainly, for his time Faraday was genius, but that they did make physics after it? There were still such brilliant figures as Maxwell and Hertz, but even they did not understand that the dependence of the scalar potential of charge on its relative speed is the basis of entire classical electrodynamics, and that this is that basic law, from which follow the fundamental laws of electrodynamics.

III. Conclusion

Maxwell equations attest to the fact that in the free space the transverse electromagnetic waves can exist . Together with the boundary conditions these equations give the possibility to solve the problems of reflection and propagation of such waves in the locked and limited structures. With the aid of Maxwell equations it is possible to solve the problems of emission. But since the equations indicated are phenomenological, physics of such processes thus far remains not clear. Similar problems can be solved, also, with the use of potentials. This approach opens greater possibilities, but physics of the vector potential of magnetic field also up to now remained not clear. The development of the concept of scalar-vector potential, which dedicated a number of works [3-10], it made it possible to open the physical essence of a number of the fundamental laws of electrodynamics, charges connected with the motion. This concept assumes the dependence of the scalar potential of charge on its relative speed. It is obtained by the way of the symmetrization of the laws of induction with the use by the substantional derivative. This approach made possible to explain such phenomena as the phase aberration of electromagnetic waves, transverse Doppler effect, power interaction of the current carrying systems and nature of Lorentz force. In this article the new law of electro-electrical induction, which explains nature of dipole emission, will be examined on the basis of the concept of scalar-vector potential.

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Physical and Effective Electrodynamic Parameters of the Material Media

By F. F. Mende & A. S. Dubrovin
B.I. Verkin Institute, Ukraine

Abstract- The mathematical model of the temporary dispersion of electromagnetic waves in the plasmo-like media, the dielectrics and the magnetic materials with the use not of the effective frequency-dependent, and not depending on the frequency physical quantity of dielectric and magnetic constant for the case of isotropic medium with the sizes, the much large of the size of the heterogeneity of field is developed (wavelength). This becomes possible due to the calculation of the kinetic inductance of charges and their kinetic capacity on the basis of the deep understanding of the physical sense of the dispersion as a result of the attraction of the methodological approaches, borrowed from electrical engineering. It is shown that in the case indicated the traditionally utilized in the electrodynamics effective dielectric constant can be expressed through several physical quantities, which do not depend on the frequency.

Keywords: dielectric constant,dispersion, kinetic inductance, plasmon resonance, kineticcapacity.

GJRE-F Classification : FOR Code: 020302

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Physical and Effective Electrodynamic Parameters of the Material Media

F. F. Mende [α] & A. S. Dubrovin [σ]

Abstract- The mathematical model of the temporary dispersion of electromagnetic waves in the plasmo-like media, the dielectrics and the magnetic materials with the use not of the effective frequency-dependent, and not depending on the frequency physical quantity of dielectric and magnetic constant for the case of isotropic medium with the sizes, the much large of the size of the heterogeneity of field is developed (wavelength). This becomes possible due to the calculation of the kinetic inductance of charges and their kinetic capacity on the basis of the deep understanding of the physical sense of the dispersion as a result of the attraction of the methodological approaches, borrowed from electrical engineering. It is shown that in the case indicated the traditionally utilized in the electrodynamics effective dielectric constant can be expressed through several physical quantities, which do not depend on the frequency.

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I. Introduction

The classical electrodynamics of material media is one of the most important branches of physics not only on its theoretical, but also, in not smaller measure, to practical significance. Nevertheless, the traditional study even of this basic for it problem, as the frequency dispersion of electromagnetic waves [1-5], it does not manage without essential omissions and weak places.It is widely-known that physics is the quantitative science, based on the physical experiment, which is rested on the measurements, i.e., the comparison of the characteristics of the phenomena with the specific standards being investigated. For this in physics are introduced physical quantities, physical units of their measurement and meters. The experimentally obtained quantitative dependences make it possible to use mathematical methods for their working and to build the theoretical, i.e., mathematical models of the studied phenomena. Fundamental component of mathematical model are the functional dependences, which mutually connect different variables of the model accepted.

Such variables can be not only the physical quantities, but also the parameters of the mathematical model (briefly – the mathematical parameters), which play in the model auxiliary role. Mathematical models allow, among entire other, to quantitatively formulate (i.e., to formulate in the language of mathematics) physical laws, but in this case it is important that during the writing of physical law it is possible to use only physical quantities as the variab. This makes it possible to examine the physical sense of laws, since the mathematical parameters, in contrast to the physical quantities, are not allotted by physical sense. In particular, the mathematical parameter can be expressed by the complex number (for example, the complex dielectric constant, utilized in the method of complex amplitudes), while physical quantity cannot be complex-valued (for example, the relative dielectric constant of medium). The given examples are trivial, but in cases when the sequential analysis of the physical sense of dependences is difficult, confusion in the differentiation of the physical quantities and mathematical parameters can app ear.

By all is well known this phenomenon as rainbow. To any specialist in the electrodynamics it is clear that the appearance of rainbow is connected with the dependence on the frequency of the phase speed of the electromagnetic waves, passing through the drops of rain. Since water is dielectric, with the explanation of this phenomenon Heaviside and Vul assumed that this dispersion was connected with the frequency dispersion (dependence on the frequency) of the dielectric constant of water. Since then this point of view is ruling [1-6].

Let us recall that the relative dielectric constant of medium – this is the physical quantity, which characterizes the dielectric properties of medium and which shows, by how many times the force of interaction of two electric charges in this medium is less than in the vacuum. However, frequency characterizes separate monochromatic component of electromagnetic wave and straight relation to the electric field a charge it does not have. Consequently, speaking about the frequency dispersion of dielectric constant, Heaviside and Vul had in the form a dependence on the frequency not of the physical quantity of the relative dielectric constant of medium, but some new mathematical parameter.

Certainly, to avoid confusion, better there would be this dielectric constant to name other (for example, by effective dielectric constant), similarly, as complex dielectric constant is not called relative dielectric constant. But for some reason these famous scientists of this did not make, apparently, simply hoping for the fact that misunderstandings it will not be. Especially

Author α σ: e-mails: mende_fedor@mail.ru, asd_kiziltash@mail.ru

because already Maxwell noted [7], that relative dielectric constant it is constant.

As the idea of the dispersion of dielectric and magnetic constant was born, and what way it was past, sufficiently colorfully characterizes quotation from the monograph of well well-known specialists in the field of physics of plasma [1]: "J. itself. Maxwell with the formulation of the equations of the electrodynamics of material media considered that the dielectric and magnetic constants are the constants (for this reason they long time they were considered as the constants). It is considerably later, already at the beginning of this century with the explanation of the optical dispersion phenomena (in particular the phenomenon of rainbow) Heaviside and Vul showed that the dielectric and magnetic constants are the functions of frequency. But very recently, in the middle of the 50's, physics they came to the conclusion that these values depend not only on frequency, but also on the wave vector. On the essence, this was the radical breaking of the existing ideas. It was how a serious, is characterized the case, which occurred at the seminar I. D. Landau into 1954 during the report of A. I. Akhiezer on this theme of Landau suddenly exclaimed, after smashing the speaker: " This is delirium, since the refractive index cannot be the function of refractive index". Note that this said I. D. Landau - one of the outstanding physicists of our time" (end of the quotation). It is incomprehensible from the given quotation, that precisely had in the form Landau. However, its subsequent publications speak, that it accepted this concept [2]. And again for some reason, following Heaviside and Vul, Landau did not introduce new name for the new mathematical parameter. Hardly this outstanding physicist XX of century could not understand this obvious thing, that the discussion deals precisely with the new mathematical parameter. It is faster, so it considered that misunderstandings it will not be.

However, a similar examination occurred in a number of fundamental works on electrodynamics [2-6], as a result what in physics solidly it was fastened this concept as the frequency dispersion of the dielectric constant of material media and, in particular, plasma. The propagation of this concept to the dielectrics led to the ideas about the fact that their dielectric constant also depends on frequency. There is the publications of such well-known scholars as the Drudes, Heaviside, Landau, Ginsburg, Akhiezer, Tamm [2-6], where it is indicated that the dielectric constant of plasma and dielectrics depends on frequency.

Unfortunately, this caused many misunderstandings. Thus, many specialists cannot believe in the fact that the physical quantity of the relative dielectric constant of plasma is equal to the relative dielectric constant of vacuum, but the dispersion of the physical quantity of the dielectric constant of dielectrics is absent. However, main negative moment here lies in the fact that is not accentuated the attention of researchers in the urgency of the improvement of the mathematical models of the dispersion of electromagnetic waves in the direction of passage from the examination of the mathematical parameter by the name of dielectric constant to the examination of the physical quantity of relative dielectric constant.

The construction of such models of dispersion is possible only on the basis of a fundamental understanding of the physical sense of the proceeding processes. But precisely such models can describe those aspects of the phenomena, which previously proved to be inaccessible for the theoretical studies. Further we will show how the proper determination of the role and position for the kinetic inductance of charges in the electrodynamics it allows with the examination of the phenomenon of the dispersion of electromagnetic waves to limit to the use only of physical quantity of the relative dielectric constant of medium without the attraction of the corresponding mathematical parameters.

Contemporary electrodynamics in general form uses the conventional concept of the tensor of complex dielectric constant (tensor of magnetic permeability for the anisotropic media, including of those limited, it is ambiguously determined and it is not necessary), which considers frequency (temporary) and spatial dispersion. In the electrically isotropic media the tensor degenerates into scalar. If the dimensions of electrodynamic system are much greater the dimensions of the heterogeneity of field (wavelength of emission), then it is possible to disregard the effects of spatial dispersion and to examine only temporary dispersion. Let us further limit to the examination of precisely this special case.

II. Plasmo-Like and Conducting Media

By plasma media we will understand such, in which the charges can move without the losses. To such media in the first approximation, can be related the superconductors, free electrons or ions in the vacuum (subsequently conductors). In the absence magnetic field in the media indicated equation of motion for the electrons takes the form:

$$m\frac{d\mathbf{v}}{dt}=e\mathbf{E}\,, \qquad (2.1)$$

Where m - mass electron, e - electron charge, $\mathbf{E}$ - tension of electric field, $\mathbf{v}$ - speed of the motion of charge.

`In this equation is considered that the electron charge is negative. In [15] it is shown that this equation can be disseminated to the case of electron motion in the hot plasma.

Global Journal of Researches in Engineering (F) Volume XVI Issue IV Version I Year 2016

Using an interrelation of the current densities and electrons

$$\mathbf{j}=ne\mathbf{v}, \qquad (2.2)$$

from (2.1) we obtain the current density of the conductivity

$$\mathbf{j}_L=\frac{ne^2}{m}\int \mathbf{E}dt. \qquad (2.3)$$

After introducing the accordingly [8-12] specific kinetic inductance of charge carriers, whose existence is connected with the inertia properties of massive charge carriers,

$$L_k=\frac{m}{ne^2}, \qquad (2.4)$$

let us write down equality (2.3) in the form

$$\mathbf{j}_L=\frac{1}{L_k}\int \mathbf{E}dt. \qquad (2.5)$$

The relationship (2.5) it will be written down for the case of harmonicsfields $\mathbf{E}=\mathbf{E}_0 \sin \omega t$:

$$\mathbf{j}_L=-\frac{1}{\omega L_k}\mathbf{E}_0 \cos \omega t. \qquad (2.6)$$

Here and throughout, as a rule, is used not the complex, but actual form of the record of electrodynamic formulas because of its clarity for the reflection of the phase relationships between the vectors, which represent electric fields and current densities.

From relationship (6.5) and (6.6) is evident that $\mathbf{j}_L$ presents inductive current, since. its phase is late with respect to the tension of electric field to the angle $\pi/2$.

If charges are located in the vacuum, then during the presence of summed current it is necessary to consider bias current

$$\mathbf{j}_\varepsilon=\varepsilon_0\frac{\partial \mathbf{E}}{\partial t}=\varepsilon_0\mathbf{E}_0 \cos \omega t.$$

Is evident that this current bears capacitive nature, since. its phase anticipates the phase of the tension of electrical to the angle $\pi/2$. Thus, summary current density will compose [10-15]:

$$\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial \mathbf{E}}{\partial t}+\frac{1}{L_k}\int \mathbf{E}dt,$$

or pour on for the case of harmonics

$$\mathbf{j}_\Sigma=\left(\omega\varepsilon_0-\frac{1}{\omega L_k}\right)\mathbf{E}_0 \cos \omega t. \qquad (2.7)$$

If electrons are located in the material medium, then in the general case should be still considered the presence of the positively charged ions, but rapidly changing in the particular case pour on their presence it is possible not to consider in connection with the significant exceeding of the mass of the ions above the mass of electrons.

In (2.7) value in the brackets is summary susceptance of medium σ_Σ , that folding from the capacitive σ_C and σ_L inductive susceptance

$$\sigma_\Sigma=\sigma_C+\sigma_L=\omega\varepsilon_0-\frac{1}{\omega L_k}.$$

Relationship (2.7) can be rewritten and differently:

$$\mathbf{j}_\Sigma=\omega\varepsilon_0\left(1-\frac{\omega_0^2}{\omega^2}\right)\mathbf{E}_0 \cos \omega t,$$

where $\omega_0=\sqrt{\frac{1}{L_k\varepsilon_0}}$ - plasma frequency of Langmuir vibrations.

The scalar quantity thus came out

$$\varepsilon^*(\omega)=\varepsilon_0\left(1-\frac{\omega_0^2}{\omega^2}\right)=\varepsilon_0-\frac{1}{\omega^2 L_k},$$

which in the scientific literature, in particular, in the works on physics of plasma [1-6], is named the dielectric constant of plasma. If we treat this value, as the absolute dielectric constant of plasma in the sense that its relation to the electrical constant gives the physical quantity of the relative dielectric constant of plasma, then it will come out that the physical quantity of relative dielectric of the permeability of plasma depends on frequency. In the previous paragraph it was noted, that this is erroneous, and the obtained value is the certain mathematical parameter, which must be distinguished from the absolute and relative dielectric constant. In contrast to the absolute dielectric constant, which is conveniently called also in the more expanded version of designation physical absolute dielectric constant, the introduced value let us name effective absolute dielectric constant. It is analogous, in contrast to the relative dielectric constant, which is conveniently called also in the more expanded version of designation physical relative dielectric constant, let us name the ratio of the introduced value to the electrical constant effective relative dielectric constant. If the physical absolute and relative dielectric constants of medium do not depend on frequency, then the effective absolute and relative dielectric constants of medium on frequency depend.

It is important to note that the effective absolute dielectric constant of plasma proved to be the composite mathematical parameter, into which simultaneously enters electrical constant and specific kinetic inductance of the charges [16-18].

For further concrete definition of the examination of the dispersion of electromagnetic waves let us determine the concepts of the physical dielectric constants of medium (absolute and relative) for the case of variables pour on. Entering the Maxwell second equation summary current density (subsequently for the brevity we will use word "current" instead of "current density") in any medium is added only from following three components, which depend on the electric field:

1) The current of resistance losses there will be in-phase to electric field.
2) Hhepermittance current, called bias current (is determined by first-order derivative of electric field by the time and anticipates the tension of electric field on the phase on $\pi/2$);
3) The conduction current, determined by integral of the electric field from the time, will lag behind the electric field on the phase on $\pi/2$.

All these components must be present in any nonmagnetic regions with the heat losses. Therefore it is completely natural, the dielectric constant of any medium to define as the coefficient, confronting that term, which is determined by the derivative of electric field by the time in the second equation of Maxwell. In this case one should consider that this dielectric constant cannot be negative in connection with the fact that through it it is determined energy of electrical pour on, but energy is always non-negative. Accordingly, physical relative dielectric constant is equal to the ratio of physical absolute dielectric constant to the electrical constant. Let us generally note that both for the effective and for the physical dielectric constant acts the trivial general rule – the relative permeability is always equal to the ratio of absolute permeability to the electrical constant, so that word "absolute" or "relative" we will for the brevity as far as possible omit.

The proposed mathematical model of the dispersion of electromagnetic waves in the plasma is differed from the previously known the fact that not the effective, but physical dielectric constant of plasma is used. This becomes possible due to the calculation of the kinetic inductance of charges on the basis of the deep understanding of the physical sense of dispersion. As a result, the proposed model makes it possible to consider initial conditions during the solution of integrodifferential equation for the current by means of the introduction to the appropriate integration constant.

However, the physical dielectric constant of plasma in the ac fields is not determined with the traditional examination and even current is not spread to the bias current and the conduction current, one of which is determined electrical constant and derivative of electric field, but another is determined by specific kinetic inductance and integral of the electric field. To a certain degree this "dumping of currents into the total heap" is justified, since derivative and integral of the function of harmonic oscillation are distinguished only by sign. Let us emphasize that from a mathematical point of view to reach in the manner that it entered to Landau, it is possible, but in this case is lost the integration constant, which is necessary to account for initial conditions during the solution of the equation, which determines current density in the material medium.

The separation of currents in the proposed model makes it possible to better understand physics of phenomenon. One of these two antiphase competing currents depends on frequency linearly, another – it is inversely proportional to frequency. The conduction current predominates with the low frequencies, the bias current, on the contrary, predominates with the high. At the plasma current frequency are equal and enter into the resonance with each other.

Analogous with introduction to effective dielectric constant it is possible to introduce the effective (different from the physical) kinetic inductance depending on the frequency

$$L^*(\omega)=\frac{L_k}{\left(\frac{\omega^2}{\omega_0^2}-1\right)}=\frac{L_k}{\varepsilon_0\omega^2 L_k-1},$$

after writing down relationship (2.7) in the form:

$$\mathbf{j}_\Sigma=-\frac{\left(\frac{\omega^2}{\omega_0^2}-1\right)}{\omega L}\mathbf{E}_0\cos\omega t.$$

The parameters $\varepsilon^*(\omega)$, $L^*(\omega)$ make it possible to write down (2.7) in two equivalent forms:

$$\mathbf{j}_\Sigma=\omega\varepsilon^*(\omega)\mathbf{E}_0\cos\omega t,$$

$$\mathbf{j}_\Sigma=-\frac{1}{\omega L^*(\omega)}\mathbf{E}_0\cos\omega t.$$

The first of these parameters is equal to the ratio of summary susceptance of medium to the frequency, and the second is equal to the reciprocal value of the work of frequency and of susceptance of the medium:

$$\varepsilon^*(\omega)=\frac{\sigma_X}{\omega},\ L_k*(\omega)=\frac{1}{\omega\sigma_X}.$$

Natural to substitute these values in the formulas, which determine energy of electrical pour on

$$W_E = \frac{1}{2}\varepsilon_0 E_0^2$$

and kinetic energy of charge carriers

$$W_j = \frac{1}{2} L_k j_0^2 , \qquad (2.8)$$

it is simple because in these formulas not the effective, but corresponding physical quantities figure. It is not difficult to show that in this case the total specific energy can be obtained from the relationship of

$$W_\Sigma = \frac{1}{2} \cdot \frac{d\left(\omega \varepsilon^*(\omega)\right)}{d\omega} E_0^2 , \qquad (2.9)$$

from which we obtain

$$W_\Sigma = \frac{1}{2}\varepsilon_0 E_0^2 + \frac{1}{2} \ \frac{1}{\omega^2 L_k} E_0^2 = \frac{1}{2}\varepsilon_0 E_0^2 + \frac{1}{2} L_k j_0^2 \ .$$

We will obtain the same result, after using the formula

$$W = \frac{1}{2} \ \frac{d\left[\dfrac{1}{\omega L_k^*(\omega)}\right]}{d\omega} \ E_0^2 .$$

The given relationships show that the specific energy consists of potential energy of electrical pour on and to kinetic energy of charge carriers.

Wave equation follows from the appropriate system of Maxwell equations, which completely describes the electrodynamics of the non dissipative conductors:

$$\mathrm{rot}\,\mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t}, \qquad \mathrm{rot}\,\mathbf{H} = \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt , \qquad (2.10)$$

where ε_0 and μ_0 – electrical and magnetic constants. We obtain from (2.10):

$$\mathrm{rot}\ \ \mathrm{rot}\,\mathbf{H} + \mu_0\varepsilon_0 \frac{\partial^2 \mathbf{H}}{\partial t^2} + \frac{\mu_0}{L_k}\mathbf{H} = 0 \qquad (2.11)$$

For the case pour on, time-independent, equation (2.11) passes into the equation of London

$$\mathrm{rot}\ \ \mathrm{rot}\,\mathbf{H} + \frac{\mu_0}{L_k}\mathbf{H} = 0 \ ,$$

where of $\lambda_L{}^2 = \dfrac{L_k}{\mu_0}$ - London depth of penetration.

Thus, it is possible to conclude that the equations of London being a special case of equation (6.11), and do not consider bias currents on medium. Therefore they do not give the possibility to obtain the wave equations, which describe the processes of the propagation of electromagnetic waves in the superconductors.

For the electrical pour on the wave equation of signs the form:

$$\mathrm{rot}\ \ \mathrm{rot}\,\mathbf{E} + \mu_0\varepsilon_0 \frac{\partial^2 \mathbf{E}}{\partial t^2} + \frac{\mu_0}{L_k}\mathbf{E} = 0 \ .$$

For the variable electrical pour on we have:

$$\mathrm{rot}\ \ \mathrm{rot}\,\mathbf{E} + \frac{\mu_0}{L_k}\mathbf{E} = 0 \ .$$

consequently, dc fields penetrate the superconductor in the same manner as for magnetic, diminishing exponentially. However, the density of current in this case grows according to the linear law

$$\mathbf{j}_L = \frac{1}{L_k}\int \mathbf{E}dt \ .$$

It is evident from the developed mathematical model of dispersion that the physical absolute dielectric constant of this medium is connected with the accumulation of potential energy, it does not depend on frequency and it is equal to the physical absolute dielectric constant of vacuum, i.e., by electrical constant. Furthermore, this medium is characterized still and the kinetic inductance of charge carriers and this parameter determines the kinetic energy, accumulated on medium.

Thus, in contrast to the conventional procedure [2-4] of the examination of the process of the propagation of electromagnetic waves in non dissipative conducting media, the proposed procedure does not require the introduction of polarization vector, but equation of motion is assumed as the basis of examination in it, and in this case in the Maxwell second equation are extracted all components of current densities explicitly.

For further understanding of physical nature of the phenomenon of dispersion we will use the simple radio-technical method of equivalent diagrams, which makes it possible to clearly present in the form such diagrams not only radio-technical elements with the concentrated and distributed parameters, but also material media. As it will be shown below, according to this method, the single volume of conductor or plasma according to its electrodynamic characteristics is equivalent to parallel resonant circuit with the lumped parameters. Let us examine parallel resonant circuit with the parallel connection of capacity C and inductance L . The connection between the voltage U , applied to the outline, and the summed current I_Σ , which flows through this chain, takes the form

$$I_\Sigma = I_C + I_L = C\frac{dU}{dt} + \frac{1}{L}\int U dt \ ,$$

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Where $I_C = C\frac{dU}{dt}$, $I_L = \frac{1}{L}\int Udt$ – the currents, which flow through the capacity and the inductance respectively.

We obtain for the alternating voltage according to the harmonic $U = U_0 \sin \omega t$ law

$$I_\Sigma = \left(\omega C - \frac{1}{\omega L}\right) U_0 \cos \omega t . \quad (2.12)$$

In (2.12) value in the brackets there is summary susceptance σ_Σ of chain, which consists of the capacitive σ_C and σ_L inductive susceptance

$$\sigma_\Sigma = \sigma_C + \sigma_L = \omega C - \frac{1}{\omega L} .$$

In this case relationship (2.12) can be rewritten as follows:

$$I_\Sigma = \omega C \left(1 - \frac{\omega_0^2}{\omega^2}\right) U_0 \cos \omega t ,$$

where $\omega_0{}^2 = \frac{1}{LC}$ - the resonance frequency of parallel circuit.

As in the case conductors, it is possible to introduce the new mathematical parameter of the effective capacity

$$C^*(\omega) = C\left(1 - \frac{\omega_0^2}{\omega^2}\right) = C - \frac{1}{\omega^2 L} \quad (2.13)$$

depending on the frequency, capacity and even inductance and susceptance of chain to the frequency equal to relation. And it is again necessary this mathematical parameter to distinguish from the physical capacity, which is conventionally designated as simply the capacity, and which is not the mathematical parameter, but physical quantity.

Relationship (2.12) can be rewritten and differently:

$$I_\Sigma = -\frac{\left(\frac{\omega^2}{\omega_0^2} - 1\right)}{\omega L} U_0 \cos \omega t ,$$

after introducing the new mathematical parameter of the effective inductance

$$L^*(\omega) = \frac{L}{\left(\frac{\omega^2}{\omega_0^2} - 1\right)} = \frac{L}{\omega^2 LC - 1} . \quad (2.14)$$

it is the reciprocal value of the work of summary susceptance and frequency.

Using expressions (2.13, 2.14), let us write down:

$$I_\Sigma = \omega C^*(\omega)\ U_0 \cos \omega t , \quad (2.15)$$

$$I_\Sigma = -\frac{1}{\omega L^*(\omega)}\ U_0 \cos \omega t . \quad (2.16)$$

Relationships (2.15) and (2.16), using the different parameters $C^*(\omega)$ and $L^*(\omega)$, they are equivalent, and each of them completely characterizes chain.

Accumulated in the capacity and the inductance energy, is determined from the relationships

$$W_C = \frac{1}{2} C U_0{}^2 , \quad (2.17)$$

$$W_L = \frac{1}{2} L I_0{}^2 . \quad (2.18)$$

It is interesting that if we into the formulas (2.17, 2.18) instead of the physical of capacity and inductance substitute the appropriate effective values (2.13, 2.14), that it will come out that energy can be negative. The so-called problem of negative energy, which is inherent in a whole series of the mathematical models of frequency dispersion, including to Klein-Gordon equations for the scalar massive particles and Dirac for the fermions in quantum physics, appears. However, in the case of parallel resonant circuit it is obvious that the problem indicated is obliged to its appearance to the incorrect replacement of physical quantities to the appropriate effective mathematical parameters. This gives the specific orientators for the more in-depth research of the problem of negative energy in the different models of the frequency dispersion, including of quantum, but these questions already they exceed the scope of the thematics of this monograph.

It is easy to see that the summary energy, accumulated in the outline, can be expressed by the mutually equivalent equalities:

$$W_\Sigma = \frac{1}{2} \frac{d\sigma_X}{d\omega} U_0{}^2 , \quad (2.19)$$

$$W_\Sigma = \frac{1}{2} \frac{d\left[\omega C^*(\omega)\right]}{d\omega} U_0{}^2 , \quad (2.20)$$

$$W_\Sigma = \frac{1}{2} \frac{d\left(\frac{1}{\omega L^*(\omega)}\right)}{d\omega} U_0{}^2 . \quad (2.21)$$

Any of the equalities (2.19 - 2.21) gives the identical result:

$$W_\Sigma = \frac{1}{2} C U_0{}^2 + \frac{1}{2} L I_0{}^2 ,$$

where U_0 - amplitude of stress on the capacity, and I_0 - amplitude of the current, which flows through the inductance.

Thus, parallel resonant circuit can be mathematically simulated from three mutually equivalent points of view:

1) physical capacity and physical inductance form
2) outline; outline is described by the frequency-dependent effective capacity;
3) outline is described by the frequency-dependent effective inductance.

In the quasi-static regime electrodynamic processes in the conductors are similar to processes in the parallel resonant circuit with the lumped parameters. Relationships for the parallel resonant circuit are identical to relationships for the conductors during the replacement: $E_0 \to U_0$, $j_0 \to I_0$, $\varepsilon_0 \to C$, $L_k \to L$. Thus, the single volume of conductor, with the uniform distribution of electrical pour on and current densities in it, it is equivalent to parallel resonant circuit with the lumped parameters indicated. In this case the capacity of this outline is numerically equal to the dielectric constant of vacuum, and inductance is equal to the specific kinetic inductance of charges.

This approach does not require introduction into the examination of polarization vector in the conductors in contrast to the conventional procedure [2-5]. In particular, the paragraph 59 of work [2] begins with the words: "We pass now to the study of the most important question about the rapidly changing electric fields, whose frequencies are unconfined by the condition of smallness in comparison with the frequencies, characteristic for establishing the electrical and magnetic polarization of substance" (end of the quotation). These words mean that that region of the frequencies, where, in connection with the presence of the inertia properties of charge carriers, the polarization of substance will not reach its static values, is examined. With the further consideration of a question is done the conclusion that "in any variable field, including with the presence of dispersion, the polarization vector $\mathbf{P} = \mathbf{D} - \varepsilon_0 \mathbf{E}$ (here and throughout all formulas cited they are written in the system SI) preserves its physical sense of the electric moment of the unit volume of substance" (end of the quotation). Let us give the still one quotation: "It proves to be possible to establish (unimportantly - metals or dielectrics) maximum form of the function of $\varepsilon(\omega)$ with the high frequencies valid for any bodies. Specifically, the field frequency must be great in comparison with "the frequencies" of the motion of all (or, at least, majority) electrons in the atoms of this substance. With the observance of this condition it is possible with the calculation of the polarization of substance to consider electrons as free, disregarding their interaction with each other and with the atomic nuclei" (end of the quotation).

Further, as this is done and in this work, is written the equation of motion of free electron in the ac field

$$m\frac{d\mathbf{v}}{dt} = e\mathbf{E},$$

from where its displacement is located

$$\mathbf{r} = -\frac{e\mathbf{E}}{m\omega^2}.$$

Then is indicated that the polarization $\mathbf{P}$ is a dipole moment of unit volume and the obtained displacement is put into the polarization of

$$\mathbf{P} = ne\mathbf{r} = -\frac{ne^2\mathbf{E}}{m\omega^2}.$$

In this case point charge is examined, and this operation indicates the introduction of electrical dipole moment for two point charges with the opposite signs, located at a distance $\mathbf{r}$

$$\mathbf{p}_e = -e\mathbf{r},$$

where the vector $\mathbf{r}$ is directed from the negative charge toward the positive charge. This step causes bewilderment, since the point electron is examined, and in order to speak about the electrical dipole moment, it is necessary to have in this medium for each electron another charge of opposite sign, referred from it to the distance $\mathbf{r}$. In this case is examined the gas of free electrons, in which there are no charges of opposite signs. Further follows the standard procedure, when introduced thus illegal polarization vector is introduced into the dielectric constant

$$\mathbf{D} = \varepsilon_0\mathbf{E} + \mathbf{P} = \varepsilon_0\vec{E} - \frac{ne^2\mathbf{E}}{m\omega^2} = \varepsilon_0\left(1 - \frac{1}{\varepsilon_0 L_k \omega^2}\right)\mathbf{E}.$$

And since plasma frequency is determined by the relationship

$$\omega_p^{\ 2} = \frac{1}{\varepsilon_0 L_k},$$

the vector of the induction immediately is written

$$\mathbf{D} = \varepsilon_0\left(1 - \frac{\omega_p^2}{\omega^2}\right)\mathbf{E}.$$

With this approach it turns out that constant of proportionality

$$\varepsilon(\omega) = \varepsilon_0\left(1 - \frac{\omega_p^2}{\omega^2}\right),$$

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Between the electric field and the electrical induction, named dielectric constant, depends on frequency, and following it and electrical induction was declared depending on the frequency
[2-6]. But, as it was shown above, this mathematical parameter is not physical absolute dielectric constant, but ratio of summary susceptance of medium to the frequency.

Further into §61 of work [5] is examined a question about the energy of electrical and magnetic field in the media, which possess by the so-called dispersion. In this case is done the conclusion that relationship for the energy of such pour on

$$W = \frac{1}{2}\left(\varepsilon E_0{}^2 + \mu H_0{}^2\right), \qquad (2.22)$$

that making precise thermodynamic sense in the usual media, with the presence of dispersion so interpreted be cannot. These words mean that the knowledge of real electrical and magnetic pour onmedium with the dispersion insufficiently for determining the difference in the internal energy per unit of volume of substance in the presence pour on in their absence. After this assertion is given the formula, which gives the same result for enumerating the specific energy of electrical and magnetic pour on with the presence of dispersion, that also the proposed in this monograph approach:

$$W = \frac{1}{2}\frac{d\left(\omega\varepsilon(\omega)\right)}{d\omega}E_0^2 + \frac{1}{2}\frac{d\left(\omega\mu(\omega)\right)}{d\omega}H_0^2. \qquad (2.23)$$

First term in the right side (2.23) corresponds (2.9), and it means it is the total energy, which includes not only potential energy of electrical pour on, but also kinetic energy of the moving charges. This confirms conclusion about the impossibility of the interpretation precisely of formula (2.22), as the internal energy of electrical and magnetic pour on in the dispersive media, although this interpretation in the media in principle examined is possible. It consists in the fact that for the definition of the value of specific energy as the thermodynamic parameter in this case is necessary to correctly calculate this energy, taking into account not only electric field, which accumulates potential energy, but also current of the conduction electrons, which accumulate the kinetic kinetic energy of charges (6.8).

III. Transverse Plasma Resonance

The development of the mathematical model of the dispersion of electromagnetic waves in conducting media, the using a physical dielectric constant plasma, make it possible to advance the theoretically substantiated hypothesis about existence of new physical phenomenon. It can be named transverse plasma resonance in the nonmagnetized plasma. This phenomenon not only is of great theoretical interest, but also can have the important technical applications [20, 21].

Is known that the plasma resonance is longitudinal. But longitudinal resonance cannot emit transverse electromagnetic waves. However, with the explosions of nuclear charges, as a result of which is formed very hot plasma, occurs electromagnetic radiation in the very wide frequency band, up to the long-wave radio-frequency band. Today are not known those of the physical mechanisms, which could explain the appearance of this emission. On existence in the nonmagnetized plasma of any other resonances, except Langmuir, earlier known it was not, but it occurs that in the confined plasma the transverse resonance can exist, and the frequency of this resonance coincides with the frequency of Langmuir resonance, i.e., these razonansy are degenerate. Specifically, this resonance can be the reason for the emission of electromagnetic waves with the explosions of nuclear charges. For explaining the conditions for the excitation of this resonance let us examine the long line, which consists of two ideally conducting planes, as shown in Fig. 1.

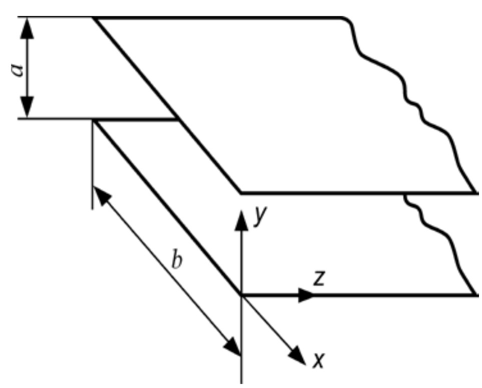

Fig. 2 : The two-wire circuit, which consists of two ideally conducting planes.

Linear (falling per unit of length) capacity and inductance of this line without taking into account edge effects they are determined by the relationships:

$$C_0 = \varepsilon_0 \frac{b}{a} \text{ and } L_0 = \mu_0 \frac{a}{b}.$$

Therefore with an increase in the length of line its total capacitance $C_\Sigma = \varepsilon_0 \frac{b}{a} z$ and summary inductance $L_\Sigma = \mu_0 \frac{a}{b} z$ increase proportional to its length.

If we into the extended line place the plasma, charge carriers in which can move without the losses, and in the transverse direction pass through the plasma the current I, then charges, moving with the definite speed, will accumulate kinetic energy. Let us note that here are not examined technical questions, as and it is possible confined plasma between the planes of line how. In this case only fundamental questions, which are concerned transverse plasma resonance in the nonmagnetic plasma, are examined.

Since the transverse current density in this line is determined by the relationship

$$j = \frac{I}{bz} = nev$$

that summary kinetic energy of the moving charges can be written down

$$W_{k\Sigma} = \frac{1}{2}\ \frac{m}{ne^2}\ abzj^2 = \frac{1}{2}\ \frac{m}{ne^2}\ \frac{a}{bz} I^2. \quad (3.1)$$

Relationship (3.1) connects the kinetic energy, accumulated in the line, with the square of current; therefore the coefficient, which stands in the right side of this relationship before the square of current, is the summary kinetic inductance of line.

$$L_{k\Sigma} = \frac{m}{ne^2} \cdot \frac{a}{bz}. \quad (3.2)$$

Thus, the value

$$L_k = \frac{m}{ne^2} \quad (3.3)$$

presents the specific kinetic inductance of charges. Relationship (7.3) is obtained for the case of the direct current, when current distribution is uniform.

Subsequently for the larger clarity of the obtained results, together with their mathematical idea, we will use the method of equivalent diagrams. The section, the lines examined, long dz can be represented in the form the equivalent diagram, shown in Fig. 2 (a).

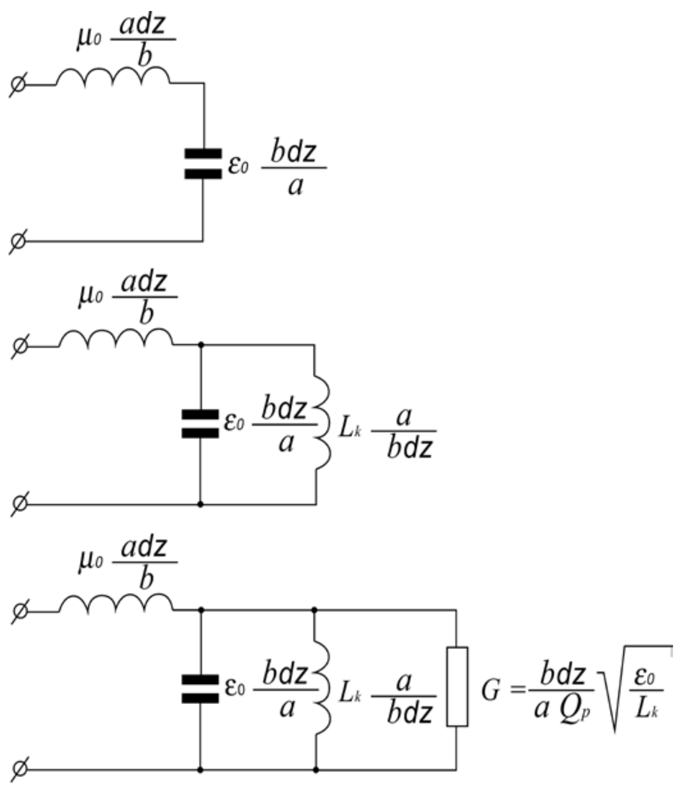

Fig. 3 : а - and the equivalent the schematic of the section of the two-wire circuit:

б - the equivalent the schematic of the section of the two-wire circuit, filled with nondissipative plasma;

в - the equivalent the schematic of the section of the two-wire circuit, filled with dissipative plasma.

From relationship (3.2) is evident that in contrast to C_Σ , L_Σ the value $L_{k\Sigma}$ with an increase in Z does not increase, but it decreases. Is connected this with the fact that with the increase Z a quantity of parallel-connected inductive elements grows.

The equivalent the schematic of the section of the line, filled with nondissipative plasma, it is shown in Fig. 3 б. The Line itself in this case will be equivalent to parallel circuit with the lumped parameters:

$$C = \frac{\varepsilon_0 bz}{a},$$

$$L = \frac{L_k a}{bz}$$

in series with which is connected the inductance

$$\mu_0 \frac{adz}{b}.$$

The resonance frequency of this outline takes the form:

$$\omega_\rho^2 = \frac{1}{CL} = \frac{1}{\varepsilon_0 L_k} = \frac{ne^2}{\varepsilon_0 m}.$$

Is obtained the very interesting result, which speaks, that the resonance frequency macroscopic of the resonator examined does not depend on its sizes. Impression can be created, that this is plasma resonance, since. the obtained value of resonance frequency exactly corresponds to the value of this resonance. But it is known that the plasma resonance characterizes longitudinal waves in the long line they, while occur transverse waves. In the case examined the value of the phase speed in the direction z is equal to infinity and the wave vector $\vec{k} = 0$.

This result corresponds to the solution of system of equations (2.10) for the line with the assigned configuration. In this case the squares of wave number, group and phase speed are determined by the relationships:

$$k_z^2 = \frac{\omega^2}{c^2}\left(1 - \frac{\omega_\rho^2}{\omega^2}\right), \quad (3.4)$$

$$v_g^2 = c^2\left(1 - \frac{\omega_\rho^2}{\omega^2}\right), \quad (3.5)$$

$$v_F^2 = \frac{c^2}{\left(1 - \frac{\omega_\rho^2}{\omega^2}\right)}, \quad (3.6)$$

where $c = \left(\frac{1}{\mu_0 \varepsilon_0}\right)^{1/2}$ - speed of light in the vacuum.

For the present instance the phase speed of electromagnetic wave is equal to infinity, which corresponds to transverse resonance at the plasma frequency. Consequently, at each moment of time pour on distribution and currents in this line uniform and it does not depend on the coordinate of , but current in the planes of line in the direction of is absent. This, from one side, it means that the inductance L_Σ will not have effects on electrodynamic processes in this line, but instead of the conducting planes can be used any planes or devices, which limit plasma on top and from below.

From relationships (3.4 - 3.6) is evident that at the point $\omega = \omega_p$ occurs the transverse resonance with the infinite quality. With the presence of losses in the resonator will occur the damping, and in the long line in this case $k_z \neq 0$, and in the line will be extended the damped transverse wave, the direction of propagation of which will be normal to the direction of the motion of charges. It should be noted that the fact of existence of this resonance is not described by other authors.

Before to pass to the more detailed study of this problem, let us pause at the energy processes, which occur in the line in the case of the absence of losses examined.

Pour on the characteristic impedance of plasma, which gives the relation of the transverse components of electrical and magnetic, let us determine from the relationship

$$Z = \frac{E_y}{H_x} = \frac{\mu_0 \omega}{k_z} = Z_0 \left(1 - \frac{\omega_\rho^2}{\omega^2}\right)^{-1/2},$$

where of $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$ - characteristic (wave) resistance of vacuum.

The obtained value Z is characteristic for the transverse electrical waves in the waveguides. With $\omega \to \omega_p$ we have: $Z \to \infty$, $H_x \to 0$. When $\omega > \omega_p$ in the plasma there is electrical and magnetic component of field. The specific energy of these pour on it takes the form:

$$W_{E,H} = \frac{1}{2}\varepsilon_0 E_{0y}^2 + \frac{1}{2}\mu_0 H_{0x}^2$$

Thus, the energy, concluded in the magnetic field, in $\left(1 - \frac{\omega_\rho^2}{\omega^2}\right)$ of times is less than the energy, concluded in the electric field. Let us note that this examination, which is traditional in the electrodynamics, is not complete, since. in this case is not taken into account one additional form of energy, namely kinetic energy of charge carriers. This examination is traditional in the electrodynamics, but is not considered kinetic energy of charge carriers. Occurs that pour on besides the waves of electrical and magnetic, that carry electrical and magnetic energy, in the plasma there exists even and the third - kinetic wave, which carries kinetic energy of current carriers. The specific energy of this wave takes the form:

$$W_k = \frac{1}{2} L_k j_0^2 = \frac{1}{2} \cdot \frac{1}{\omega^2 L_k} E_0^2 = \frac{1}{2} \varepsilon_0 \frac{\omega_\rho^2}{\omega^2} E_0^2 .$$

Consequently, the total specific energy of wave is written as

$$W_{E,H,j} = \frac{1}{2}\varepsilon_0 E_{0y}^2 + \frac{1}{2}\mu_0 H_{0x}^2 + \frac{1}{2} L_k j_0^2 .$$

Thus, for finding the total energy, by the prisoner per unit of volume of plasma, calculation only pour on E and H it is insufficient. at the point of are carried out the relationship:

$$W_H = 0$$

$$W_E = W_k$$

i.e. magnetic field in the plasma is absent, and plasma presents macroscopic electromechanical resonator with the infinite quality, ω_p resounding at the frequency.

Since with the frequencies $\omega > \omega_p$ the wave, which is extended in the plasma, it bears on itself three forms of the energy: electrical, magnetic and kinetic, then this wave can be named electric magnetic kinetic wave. Kinetic wave is the wave of the current density $\mathbf{j} = \frac{1}{L_k}\int \mathbf{E} dt$. This wave is moved with respect to the electrical wave the angle $\pi / 2$.

Until now considered physically unrealizable case where there are no losses in the plasma, which corresponds to an infinite quality factor plasma resonator. If losses are located, moreover completely it does not have value, by what physical processes such losses are caused, then the quality of plasma resonator will be finite quantity. For this case of Maxwell's equation they will take the form:

$$\operatorname{rot}\mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t},. \qquad (3.7)$$

$$\operatorname{rot}\vec{H} = \sigma_{p.ef}\,\mathbf{E} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt.$$

The presence of losses is considered by the term $\sigma_{p.ef}\mathbf{E}$. In this case designation ef emphasizes the importance of the very fact of existence of losses, but not their concrete mechanism. The value σ_{ef} determines the quality of plasma resonator. For measuring σ_{ef} should be selected the section of line by the length of z_0, whose value is considerably lower than the wavelength in the plasma. This section will be equivalent to outline with the lumped parameters:

$$C = \varepsilon_0 \frac{bz_0}{a}, \qquad (3.8)$$

$$L = L_k \frac{a}{bz_0}, \qquad (3.9)$$

$$G = \sigma_{\rho.ef}\frac{bz_0}{a}, \qquad (3.10)$$

where G - conductivity, connected in parallel C and L.

Conductivity and quality in this outline enter into the relationship:

$$G = \frac{1}{Q_\rho}\sqrt{\frac{C}{L}},$$

from where, taking into account (3.8 - 3.10), we obtain

$$\sigma_{\rho.ef} = \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}}. \qquad (3.11)$$

Thus, measuring its own quality plasma of the resonator examined, it is possible to determine $\sigma_{p.ef}$. Using (3.2) and (3.11) we will obtain

$$\operatorname{rot}\mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t},$$

$$\operatorname{rot}\mathbf{H} = \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}}\,\mathbf{E} + \varepsilon_0\frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt. \qquad (3.12)$$

The equivalent the schematic of this line, filled with dissipative plasma, is represented in Fig. 2 (в)

Let us examine the solution of system of equations (3.12) at the point $\omega = \omega_p$, in this case, since in this case

$$\varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt = 0,$$

we obtain

$$\operatorname{rot}\mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t},$$

$$\operatorname{rot}\mathbf{H} = \frac{1}{Q_P}\sqrt{\frac{\varepsilon_0}{L_k}}\mathbf{E}.$$

These relationships determine wave processes at the point of resonance.

If losses in the plasma, which fills line are small, and strange current source is connected to the line, then it is possible to assume:

$$\operatorname{rot}\mathbf{E} \cong 0,$$

$$\frac{1}{Q_p}\sqrt{\frac{\varepsilon_0}{L_k}}\mathbf{E} + \varepsilon_0\frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt = \mathbf{j}_{CT}, \qquad (3.13)$$

where $\mathbf{j}_{CT}$ - density of strange currents.

After integrating (7.13) with respect to the time and after dividing both parts to ε_0, we will obtain

$$\omega_p^2\,\mathbf{E} + \frac{\omega_p}{Q_p}\cdot\frac{\partial \mathbf{E}}{\partial t} + \frac{\partial^2 \mathbf{E}}{\partial t^2} = \frac{1}{\varepsilon_0}\cdot\frac{\partial \mathbf{j}_{CT}}{\partial t}. \qquad (3.14)$$

If we relationship (3.14) integrate over the surface of normal to the vector $\mathbf{E}$ and to introduce the electric flux $\Phi_E = \int \mathbf{E}d\mathbf{s}$ we will obtain:

$$\omega_p^2\Phi_E + \frac{\omega_p}{Q_p}\cdot\frac{\partial \Phi_E}{\partial t} + \frac{\partial^2 \Phi_E}{\partial t^2} = \frac{1}{\varepsilon_0}\cdot\frac{\partial I_{CT}}{\partial t}, \qquad (3.15)$$

where I_{CT} - strange current.

The equation (3.15) is the equation of harmonic oscillator with the right side, characteristic for the two-level laser [15]. If the source of excitation was opened, then relationship (3.14) presents "cold" laser resonator, in which the fluctuations will attenuate exponentially

$$\Phi_E(t) = \Phi_E(0)\; e^{i\omega_P t}\cdot e^{-\frac{\omega_P}{2Q_P}t},$$

i.e. it will oscillate macroscopic $\Phi_E(t)$ electric flux with the frequency ω_p. Relaxation time in this case is determined by the relationship:

$$\tau = \frac{2Q_P}{\omega_P} .$$

The problem of developing of laser consists to now only in the skill excite this resonator.

If resonator is excited by strange currents, then this resonator presents band-pass filter with the resonance frequency to equal plasma frequency and the passband $\Delta\omega = \frac{\omega_p}{2Q_p}$.

Another important practical application of transverse plasma resonance is possibility its use for warming-up and diagnostics of plasma. If the quality of plasma resonator is great, then can be obtained the high levels of electrical pour on, and it means high energies of charge carriers.

IV. Magnetic Materials

If we consider all components of current density in the conductor, then the Maxwell second equation can be written down:

$$\mathrm{rot}\,\mathbf{H} = \sigma_E \mathbf{E} + \varepsilon \frac{\partial \mathbf{E}}{\partial t} + \frac{1}{L_k}\int \mathbf{E}dt , \quad (4.1)$$

where σ_E - conductivity of metal.

At the same time, the Maxwell first equation can be written down as follows:

$$\mathrm{rot}\,\mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \quad (4.2)$$

where μ - magnetic permeability of medium. It is evident that equations (4.1) and (4.2) are asymmetrical.

To somewhat improve the symmetry of these equations are possible, introducing into equation (4.2) term linear for the magnetic field, that considers heat losses in the magnetic materials in the variable fields:

$$\mathrm{rot}\,\mathbf{E} = -\sigma_H \mathbf{H} - \mu \frac{\partial \mathbf{H}}{\partial t} , \quad (4.3)$$

where σ_H - conductivity of magnetic currents. But here there is no integral of such type, which is located in the right side of equation (4.1), in this equation. At the same time to us it is known that the atom, which possesses the magnetic moment $\mathbf{m}$, placed into the magnetic field, and which accomplishes in it precessional motion, has potential energy $U_m = -\mu \mathbf{mH}$. Therefore potential energy can be accumulated not only in the electric fields, but also in the precessional motion of magnetic moments, which does not possess inertia. Similar case is located also in the mechanics, when the gyroscope, which precesses in the field of external gravitational forces, accumulates potential energy. Regarding mechanical precessional motion is also noninertial and immediately ceases after the removal of external forces. For example, if we from under the precessing gyroscope, which revolves in the field of the earth's gravity, rapidly remove support, thus it will begin to fall, preserving in the space the direction of its axis, which was at the moment, when support was removed. The same situation occurs also for the case of the precessing magnetic moment. Its precession is noninertial and ceases at the moment of removing the magnetic field.

Therefore it is possible to expect that with the description of the precessional motion of magnetic moment in the external magnetic field in the right side of relationship (4.3) can appear a term of the same type as in relationship (4.1). It will only stand L_k, i.e., instead C_k the kinetic capacity[23,24], which characterizes that potential energy, which has the precessing magnetic moment in the magnetic field:

$$\mathrm{rot}\,\mathbf{E} = -\sigma_H \mathbf{H} - \mu \frac{\partial \mathbf{H}}{\partial t} - \frac{1}{C_k}\int \mathbf{H}dt . \quad (4.4)$$

For the first time this idea of the first equation of Maxwell taking into account kinetic capacity was given in the work [25].

Let us explain, can realize this case in practice, and that such in this case kinetic capacity. Resonance processes in the plasma and the dielectrics are characterized by the fact that in the process of fluctuations occurs the alternating conversion of electrostatic energy into the kinetic kinetic energy of charges and vice versa. This process can be named electric kinetic and all devices: lasers, masers, filters, etc, which use this process, can be named electric kinetic. At the same time there is another type of resonance - magnetic. If we use ourselves the existing ideas about the dependence of magnetic permeability on the frequency, then it is not difficult to show that this dependence is connected with the presence of magnetic resonance. In order to show this, let us examine the concrete example of ferromagnetic resonance. If we magnetize ferrite, after applying the stationary field H_0 in parallel to the axis z, the like to relation to the external variable field medium will come out as anisotropic magnetic material with the complex permeability in the form of tensor [26]

$$\mu = \begin{pmatrix} \mu_T{}^*(\omega) & -i\,\alpha & 0 \\ i\,\alpha & \mu_T{}^*(\omega) & 0 \\ 0 & 0 & \mu_L \end{pmatrix} ,$$

where

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$$\mu_T*(\omega)=1-\frac{\Omega\ |\gamma|\ M_0}{\mu_0(\omega^2-\Omega^2)},\qquad \alpha=\frac{\omega\ |\gamma|\ M_0}{\mu_0(\omega^2-\Omega^2)},\qquad \mu_L=1$$

moreover

$$\Omega=|\gamma|\,H_0 \tag{4.4}$$

is natural frequency of precession, and

$$M_0=\mu_0(\mu-1)H_0 \tag{4.5}$$

is a magnetization of medium. Taking into account (4.4) and (4.5) for $\mu_T*(\omega)$, it is possible to write down

$$\mu_T*(\omega)=1-\frac{\Omega^2(\mu-1)}{\omega^2-\Omega^2}. \tag{4.6}$$

It came out that magnetic permeability of magnetic material depends on frequency, and appears the assumption that this case must be examined analogously with the case with the plasma.

If we consider that the electromagnetic wave is propagated along the axis X and there are components pour on H_y of and H_z, then in this case the Maxwell first equation will be written down:

$$rot\mathbf{E}=\frac{\partial\mathbf{E}_Z}{\partial x}=\mu_0\mu_T\frac{\partial\mathbf{H}_y}{\partial t}.$$

Taking into account (4.6), we will obtain

$$\mathrm{rot}\,\mathbf{E}=\mu_0\left[1-\frac{\Omega^2(\mu-1)}{\omega^2-\Omega^2}\right]\frac{\partial\mathbf{H}_y}{\partial t}.$$

for the case of $\omega>>\Omega$ we have

$$\mathrm{rot}\,\mathbf{E}=\mu_0\left[1-\frac{\Omega^2(\mu-1)}{\omega^2}\right]\frac{\partial\mathbf{H}_y}{\partial t}. \tag{4.7}$$

assuming $H_y=H_{y0}\sin\omega t$ and taking into account that in this case

$$\frac{\partial\mathbf{H}_y}{\partial t}=-\omega^2\int\mathbf{H}_y\,dt,$$

we obtain from (4.7)

$$\mathrm{rot}\,\mathbf{E}=\mu_0\frac{\partial\mathbf{H}_y}{\partial t}+\mu_0\,\Omega^2(\mu-1)\int\mathbf{H}_y\,dt,$$

or

$$\mathrm{rot}\,\mathbf{E}=\mu_0\frac{\partial\mathbf{H}_y}{\partial t}+\frac{1}{C_k}\int\mathbf{H}_y\,dt. \tag{4.8}$$

for the case $\omega<<\Omega$ we find

$$\mathrm{rot}\,\mathbf{E}=\mu_0\mu\frac{\partial\mathbf{H}_y}{\partial t}.$$

Value

$$C_k=\frac{1}{\mu_0\,\Omega^2(\mu-1)},$$

which is introduced in relationship (4.8), let us name kinetic capacity.

With which is connected existence of this parameter, and its what physical sense? If the direction of magnetic moment does not coincide with the direction of external magnetic field, then the vector of this moment begins to precess around the vector of magnetic field with the frequencyΩ. The magnetic moment of $\mathbf{m}$ possesses in this case potential energy $U_m=-\mathbf{m}\cdot\mathbf{B}$. This energy similar to energy of the charged capacitor is potential, because precessional motion, although is mechanical, however, it not inertia and instantly it does cease during the removal of magnetic field. However, with the presence of magnetic field precessional motion continues until the accumulated potential energy is spent, and the vector of magnetic moment will not become parallel to the vector of magnetic field.

The equivalent diagram of the case examined is given in Fig. (3) At the point $\omega=\Omega$ occurs magnetic resonance, in this case $\mu_T*(\omega)\to-\infty$. The resonant frequency ofthe macroscopic magneticresonatoris easily seenfromthe equivalent circuitis also independent ofthe size oflines andequal to Ω..Thus, the parameter

$$\mu_H*(\omega)=\mu_0\left[1-\frac{\Omega^2(\mu-1)}{\omega^2-\Omega^2}\right]$$

is the frequency dependent magnetic permeability, but it is the combined parameter, including μ_0, μ и C_k, which are included on in accordance with the equivalent diagram, depicted in Fig. 4.

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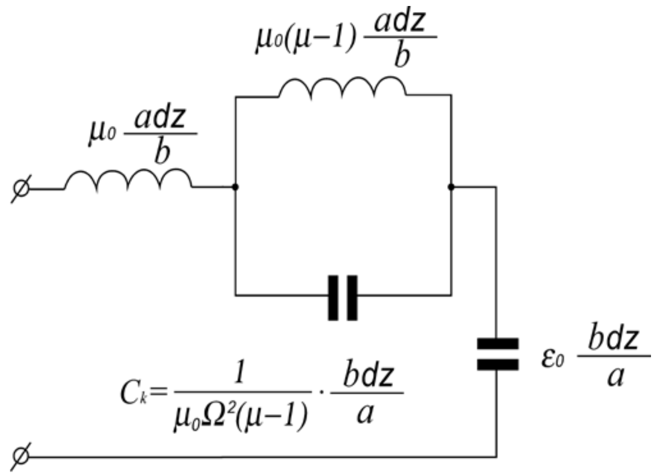

Fig. 3 : Equivalent the schematic of the two-wire circuit of that filled with magnetic material.

Is not difficult to show that in this case there are three waves: electrical, magnetic and the wave, which carries potential energy, which is connected with the precession of magnetic moments around the vector H_0. For this reason such waves can be named electric magnetic potentsial wave. Before the appearance of a work [25] in the electrodynamics this concept, as kinetic capacity it was not used, although this the real parameter has very intelligible physical interpretation.

V. DIELECTRICS

In the existing literature there are no indications that the kinetic inductance of charge carriers plays some role in the electrodynamic processes in the dielectrics. This not thus [27-28]. This parameter in the electrodynamics of dielectrics plays not less important role, than in the electrodynamics of conductors. Let us examine the simplest case, when oscillating processes in atoms or molecules of dielectric obey the law of mechanical oscillator [28]. Let us write down the equation of motion

$$\left(\frac{\beta}{m}-\omega^2\right)\mathbf{r}_m=\frac{e}{m}\mathbf{E}, \qquad (5.1)$$

where $\mathbf{r}_m$ - deviation of charges from the position of equilibrium, β - coefficient of elasticity, which characterizes the elastic electrical binding forces of charges in the atoms and the molecules. Introducing the resonance frequency of the bound charges

$$\omega_0=\frac{\beta}{m},$$

we obtain from (5.1):

$$\mathbf{r}_m=-\frac{e\,\mathbf{E}}{m(\omega^2-\omega_o^2)}. \qquad (5.2)$$

Is evident that in relationship (9.2) as the parameter is present the natural vibration frequency, into which enters the mass of charge. This speaks, that the inertia properties of the being varied charges will influence oscillating processes in the atoms and the molecules.

Since the general current density on Wednesday consists of the bias current and conduction current

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}+ne\mathbf{v},$$

that, finding the speed of charge carriers in the dielectric as the derivative of their displacement through the coordinate

$$\mathbf{v}=\frac{\partial\mathbf{r}_m}{\partial t}=-\frac{e}{m(\omega^2-\omega_o^2)}\frac{\partial\mathbf{E}}{\partial t},$$

from relationship (5.2) we find

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}-\frac{1}{L_{kd}(\omega^2-\omega_0^2)}\frac{\partial\mathbf{E}}{\partial t}. \qquad (5.3)$$

Let us note that the value

$$L_{kd}=\frac{m}{ne^2}$$

presents the kinetic inductance of the charges, entering the constitution of atom or molecules of dielectrics, when to consider charges free. Therefore relationship (5.3) it is possible to rewrite

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\left(1-\frac{1}{\varepsilon_0 L_{kd}(\omega^2-\omega_0^2)}\right)\frac{\partial\mathbf{E}}{\partial t}. \qquad (5.4)$$

Since the value

$$\frac{1}{\varepsilon_0 L_{kd}}=\omega_{pd}^{\;2}$$

it represents the plasma frequency of charges in atoms and molecules of dielectric, if we consider these charges free, then relationship (5.4) takes the form:

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_{\Sigma}=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right)\frac{\partial \mathbf{E}}{\partial t}. \qquad (5.5)$$

And again it is possible to name the value

$$\varepsilon^*(\omega)=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right) \qquad (5.6)$$

by the effective dielectric constant of dielectric. It furthermore depends on frequency. But this mathematical parameter is not the physical dielectric constant of dielectric, but has composite nature. It includes now those not already three depending on the frequency of the value: electrical constant, natural frequency of atoms or molecules and plasma frequency for the charge carriers, entering their composition, if we consider charges free.

Let us examine two limiting cases:

1. $\omega << \omega_0$,then from (5.5) we obtain

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_{\Sigma}=\varepsilon_0\left(1+\frac{\omega_{pd}{}^2}{\omega_0{}^2}\right)\frac{\partial \mathbf{E}}{\partial t}. \qquad (5.7)$$

In this case the coefficient, confronting the derivative, does not depend on frequency, and it presents the static dielectric constant of dielectric. As we see, it depends on the natural frequency of oscillation of atoms or molecules and on plasma frequency. This result is intelligible. Frequency in this case proves to be such low that the charges manage to follow the field and their inertia properties do not influence electrodynamic processes. In this case the bracketed expression in the right side of relationship (5.7) presents the static dielectric constant of dielectric. As we see, it depends on the natural frequency of oscillation of atoms or molecules and on plasma frequency. Hence immediately we have a prescription for creating the dielectrics with the high dielectric constant. In order to reach this, should be in the assigned volume of space packed a maximum quantity of molecules with maximally soft connections between the charges inside molecule itself.

2. The case, when $\omega >> \omega_0$ is exponential. In this case

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_{\Sigma}=\varepsilon_0\left(1-\frac{\omega_{pd}{}^2}{\omega^2}\right)\frac{\partial \mathbf{E}}{\partial t}$$

and dielectric became conductor (plasma) since. the obtained relationship exactly coincides with the equation, which describes plasma.

One cannot fail to note the circumstance that in this case again nowhere was used this concept as polarization vector, but examination is carried out by the way of finding the real currents in the dielectrics on the basis of the equation of motion of charges in these media. In this case in this mathematical model as the initial electrical characteristics of medium are used the values, which do not depend on frequency.

From relationship (5.5) is evident that in the case of fulfilling the equality of $\omega=\omega_0$, the amplitude of fluctuations is equal to infinity. This indicates the presence of resonance at this point. The infinite amplitude of fluctuations occurs because of the fact that they were not considered losses in the resonance system, in this case its quality was equal to infinity. In a certain approximation it is possible to consider that lower than the point indicated we deal concerning the dielectric, whose dielectric constant is equal to its static value. Higher than this point we deal already actually concerning the metal, whose density of current carriers is equal to the density of atoms or molecules in the dielectric.

Now it is possible to examine the question of why dielectric prism decomposes polychromatic light into monochromatic components or why rainbow is formed. For this the phase speed of electromagnetic waves in the medium in question must depend on frequency (frequency wave dispersion). If we to relationship (5.5) add the Maxwell first equation, then we will obtain:

$$\mathrm{rot}\,\mathbf{E}=-\mu_0\frac{\partial \mathbf{H}}{\partial t}$$

$$\mathrm{rot}\,\mathbf{H}=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right)\frac{\partial \mathbf{E}}{\partial t},$$

from where we immediately find the wave equation:

$$\nabla^2\mathbf{E}=\mu_0\varepsilon_0\left(1-\frac{\omega_{pd}{}^2}{\omega^2-\omega_0{}^2}\right)\frac{\partial^2 \mathbf{E}}{\partial t^2}.$$

If one considers that

$$\mu_0\varepsilon_0=\frac{1}{c^2},$$

where c - the speed of light, then is easy to see that in the dielectrics the frequency dispersion occurs. But this dependence of phase speed on the frequency is connected not with the dependence of physical dielectric constant on the frequency. In the formation of this dispersion it will participate immediately three, which do not depend on the frequency, physical quantities: the self-resonant frequency of atoms themselves or molecules, the plasma frequency of charges, if we consider it their free, and the dielectric constant of vacuum.

Now let us show the weak places of the traditional approach, based on the use of a concept of polarization vector,

$$\mathbf{P} = -\frac{ne^2}{m}\cdot\frac{1}{(\omega^2-\omega_0^2)}\mathbf{E}.$$

Its dependence on the frequency, is connected with the presence of mass in the charges, entering the constitution of atom and molecules of dielectrics. The inertness of charges is not allowed for this vector, following the electric field, to reach that value, which it would have in the permanent fields. Since the electrical induction is determined by the relationship:

$$\mathbf{D}=\varepsilon_0\mathbf{E}+\mathbf{PE}=\varepsilon_0\mathbf{E}-\frac{ne^2}{m}\cdot\frac{1}{(\omega^2-\omega_0^2)}\mathbf{E}, \qquad (5.8)$$

That, introduced thus, it depends on frequency.
If this induction was introduced into the second equation of Maxwell, then it signs the form:

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}+\frac{\partial\mathbf{P}}{\partial t}$$

or

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}-\frac{ne^2}{m}\frac{1}{(\omega^2-\omega_0{}^2)}\frac{\partial\mathbf{E}}{\partial t}, \qquad (5.9)$$

where $\mathbf{j}_\Sigma$ - the summed current, which flows through the model. In expression (5.9) the first member of right side presents bias current in the vacuum, and the second - current, connected with the presence of bound charges in atoms or molecules of dielectric. In this expression again appeared the specific kinetic inductance of the charges, which participate in the oscillating process

$$L_{kd}=\frac{m}{ne^2}.$$

This kinetic inductance determines the inductance of bound charges. Taking into account this relationship (5.9) it is possible to rewrite

$$\mathrm{rot}\,\mathbf{H}=\mathbf{j}_\Sigma=\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}-\frac{1}{L_{kd}}\frac{1}{(\omega^2-\omega_0{}^2)}\frac{\partial\mathbf{E}}{\partial t}.$$

Obtained expression exactly coincides with relationship (5.3). Consequently, the eventual result of examination by both methods coincides, and there are no claims to the method from a mathematical point of view. But from a physical point of view, and especially in the part of the awarding to the parameter, introduced in accordance with relationship (5.8) of the designation of electrical induction, are large claims, which we discussed. These are the physical quantity of electrical induction, but the certain composite mathematical parameter. In the essence, physically substantiated is the introduction to electrical induction in the dielectrics only in the static electric fields.

Let us show that the equivalent the schematic of dielectric presents the sequential resonant circuit, whose inductance is the kinetic inductance L_{kd}, and capacity is equal to the static dielectric constant of dielectric minus the capacity of the equal dielectric constant of vacuum. In this case outline itself proves to be that shunted by the capacity, equal to the specific dielectric constant of vacuum. For the proof of this let us examine the sequential oscillatory circuit, when the inductance of L and the capacity of C are connected in series.

The connection between the current I_C, which flows through the capacity C, and the voltage U_C, applied to it, is determined by the relationships:

$$U_C=\frac{1}{C}\int I_C dt$$

and

$$I_C=C\frac{dU_C}{dt}. \qquad (5.10)$$

This connection will be written down for the inductance:

$$I_L=\frac{1}{L}\int U_L dt$$

and

$$U_L=L\frac{dI_L}{dt}.$$

If the current, which flows through the series circuit, changes according to the law $I=I_0\sin\omega t$, then a voltage drop across inductance and capacity they are determined by the relationships

$$U_L=\omega L I_0\cos\omega t$$

and

$$U_C=-\frac{1}{\omega C}I_0\cos\omega t,$$

and total stress applied to the outline is equal

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$$U_\Sigma=\left(\omega L-\frac{1}{\omega C}\right)I_0\cos\omega t\ .$$

In this relationship the value, which stands in the brackets, presents the reactance of sequential resonant circuit, which depends on frequency. The stresses, generated on the capacity and the inductance, are located in the reversed phase, and, depending on frequency, outline can have the inductive, the whether capacitive reactance. At the point of resonance the summary reactance of outline is equal to zero.

It is obvious that the connection between the total voltage applied to the outline and the current, which flows through the outline, will be determined by the relationship

$$I=-\frac{1}{\omega\left(\omega L-\frac{1}{\omega C}\right)}\frac{\partial U_\Sigma}{\partial t}\ . \qquad (5.11)$$

The resonance frequency of outline is determined by the relationship

$$\omega_0=\frac{1}{\sqrt{LC}}\ ,$$

therefore let us write down

$$I=\frac{C}{\left(1-\frac{\omega^2}{\omega_0{}^2}\right)}\frac{\partial U_\Sigma}{\partial t}\ . \qquad (5.12)$$

Comparing this expression with relationship (5.10) it is not difficult to see that the sequential resonant circuit, which consists of the inductance L and capacity C, it is possible to present to the capacity of in the form dependent on the frequency

$$C(\omega)=\frac{C}{\left(1-\frac{\omega^2}{\omega_0{}^2}\right)}\ . \qquad (5.13)$$

The inductance is not lost with this idea, since it enters into the resonance frequency of the outline ω_0 .
Relationships (5.12) (5.11) are equivalent. Consequently, value $C(\omega)$ is not the physical capacitance value of outline, but is the certain composite mathematical parameter.
Relationship (5.11) can be rewritten and differently:

$$I=-\frac{1}{L\left(\omega^2-\omega_0{}^2\right)}\frac{\partial U_\Sigma}{\partial t}$$

and to consider that

$$C(\omega)=-\frac{1}{L\left(\omega^2-\omega_0{}^2\right)}\ . \qquad (5.14)$$

Is certain, the parameter $C(\omega)$, introduced in accordance with relationships (5.13) and (5.14) no to capacity refers.
Let us examine relationship (9.12) for two limiting cases:
1. When $\omega<<\omega_0$, we have

$$I=C\frac{\partial U_\Sigma}{\partial t}\ .$$

This result is intelligible, since. at the low frequencies the reactance of the inductance, connected in series with the capacity, is considerably lower than the capacitive and it is possible not to consider it.
the equivalent the schematic of the dielectric, located between the planes of long line is shown in Fig. 4.
2. For the case, when $\omega>>\omega_0$, we have

$$I=-\frac{1}{\omega^2 L}\frac{\partial U_\Sigma}{\partial t}\ . \qquad (5.15)$$

Taking into account that for the harmonic signal

$$\frac{\partial U_\Sigma}{\partial t}=-\omega^2\int U_\Sigma dt\ ,$$

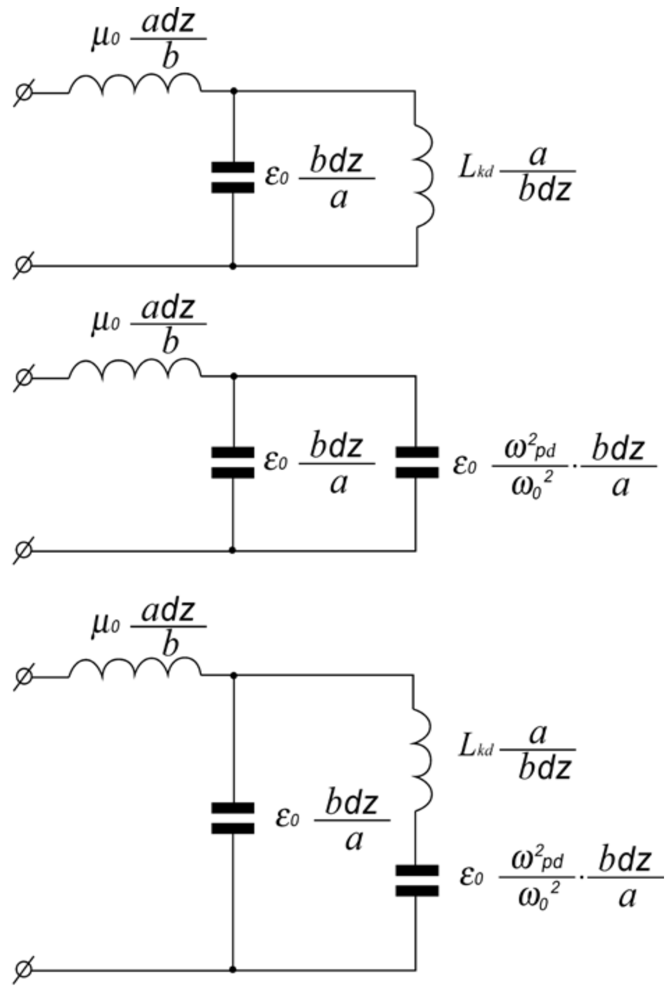

Fig. 8 : a- the equivalent the schematic of the section of the line, filled with dielectric, for the case $\omega >> \omega_0$;б - the equivalent the schematic of the section of line for the case $\omega << \omega_0$; в - the equivalent the schematic of the section of line for entire frequency band.

we obtain from (5.15):

$$I_L = \frac{1}{L}\int U_\Sigma dt .$$

In this case the reactance of capacity is considerably less than in inductance and chain has inductive reactance.

the carried out analysis speaks, that is in practice very difficult to distinguish the behavior of resonant circuits of the inductance or of the capacity. In order to understand the true composition of the chain being investigated it is necessary to remove the amplitude and phase response of this chain in the range of frequencies. In the case of resonant circuit this dependence will have the typical resonance nature, when on both sides resonance the nature of reactance is different. However, this does not mean that real circuit elements: capacity or inductance depend on frequency.

In Fig. 4 (a) and 4 (б) are shown two limiting cases. In the first case, when $\omega >> \omega_0$, dielectric according to its properties corresponds to conductor, in the second case, when $\omega << \omega_0$, it corresponds to the dielectric, which possesses the static dielectric constant of $\varepsilon = \varepsilon_0 \left(1 + \frac{\omega_{pd}^2}{\omega_0^2}\right)$

Thus, it is possible to draw the conclusion that the use of a term “dielectric constant of dielectrics” in the context of its dependence on the frequency is not completely correct. If the discussion deals with the dielectric constant of dielectrics, with which the accumulation of potential energy is connected, then correctly examine only static permeability, which is the constant, which does not depend on the frequency. Specifically, static permeability enters into all relationships, which characterize the electrodynamic characteristics of dielectrics.

the most interesting results of applying such new approaches occur precisely for the dielectrics. In this case each connected pair of charges presents the separate unitary unit with its individual characteristics and its participation in the processes of interaction with the electromagnetic field (if we do not consider the connection between the separate pairs) strictly individually. Certainly, in the dielectrics not all dipoles have different characteristics, but there are different groups with similar characteristics, and each group of bound charges with the identical characteristics will resound at its frequency. Moreover the intensity of absorption, and in the excited state and emission, at this frequency will depend on a relative quantity of pairs of this type. Therefore the partial coefficients, which consider their statistical weight in this process, can be introduced. Furthermore, these processes will influence the anisotropy of the dielectric properties of molecules themselves, which have the specific electrical orientation in crystal lattice. By these circumstances is determined the variety of resonances and their intensities, which is observed in the dielectric media. The lines of absorption or emission, when there is a electric coupling between the separate groups of emitters, acquire even more complex structure. In this case the lines can be converted into the strips. Such individual approach to each separate type of the connected pairs of charges could not be realized within the framework earlier than the existing approaches.

Should be still one important circumstance, which did not up to now obtain proper estimation. With the examination of processes in the material media, which they are both conductors and dielectrics in all relationships together with the dielectric and magnetic constant figures the kinetic inductance of charges [13]. This speaks, that the role of this parameter with the examination of processes in the material media has not less important role, than dielectric and magnetic constant. This is for the first time noted in a number the already mentioned sources, including in the recently published article [29].

VI. Conclusion

Work examines two concepts, which determine the dielectric constant of material media. Is most extended the concept of the tensor of complex dielectric constant, which depends on frequency. But this value is not the physical quantity, but the mathematical parameter, which can be with the specific assumptions determined through several not depending on the frequency physical quantities. This parameter is named effective dielectric constant. At the same time in the work is used the concept of physical dielectric constant, which does not depend on frequency. The same procedures are carried out with respect to magnetic permeability of magnetic materials. This approach removes those misunderstandings, which are connected with the insufficient understanding of the physical sense of the mathematical models of the temporary dispersion of electromagnetic waves in the isotropic media with the use of the frequency-dependent dielectric constant.

VII. Appreciation

The authors express large appreciation to professor Henri Amvrosevich Rukhadze for the consideration of new approaches to the interpretation of the frequency dispersion of the propagation of electromagnetic waves and different media. Its councils contributed to an improvement in the scientific results of article.

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Design & Development of Electric Cable Inspection

By Md. Nasir Uddin, MM Rashid, MG Mostafa, Belayet H, SM Salam, NA Nithe, MA Aziz & S Halder

International Islamic University Malaysia, Malaysia

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GJRE-F Classification : FOR Code: 090699, 090609

DESIGNDEVELOPMENTOFELECTRCCABLEINSPECTION

Design & Development of Electric Cable Inspection

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Abstract- Previously, electric cable inspection are being done by human. With the advancement of nowadays technology, robot are now being implemented in this situation in order to replace the old-fashioned inspection methods. In this report, the aim of this project is to develop a functional electric cable inspection robot that are able to navigate along electric cables. This robotic device will be able to avoid the electric poles and obstacles as well as to capture and record the defects of the electric cable by using the camera attached to it. This robot need to be in stable condition in order for it not to toppled down or tilt down when doing the inspection. In this project, a new design of the robot are being developed in order for it to achieve its objectives. The user operating system consists of four DC servo motors, two micro DC motor, a remote controller, two cameras, two balancing bar and a screen to display the video feed. This report includes brief discussion on previous methods and robots, theory of operation, design summary, stability analysis and the expected budget for this electric cable inspection robot.

Chapter 1

I. Introduction

a) Background

In today's world, there are many innovation and development that have been produced by the engineers and scientists around the world. One of them is the electric cable inspection robot which is able to help human to do their works. This type of robot can move along a cbale as well as to overcome obstacles along its way.

Previously, the maintenance of the electric cables have being done by using humans. A person requires to move along the electric cable in order for them to check the condition of the cable. This type of jobs are very dangerous to human even though all the safety procedure are being taken into consideration. Due to tis reason, the researches abroad have developed few robots that can move along the electric cable in order to help human in his dangerous job. This type of robot are remotely controlled by the specialist worker from the ground without moving along the power lines. One o f the robot that has been developed is the Expliner. Expliner was developed primarily as a robot to inspect live lines, perform detailed inspections and also have enough mobility in order to overcome the obstacles along the electric cable (Paulo Debenest & Michele Guarnieri, 2010).

In this report, I will present a study on the development of the electric cable inspection robot which can move along a suspended electric cable as well as to overcome the obstacle. Moreover, this robot will also capture the image and record the video of the cable while moving along the electric cable and able to balance itself while overcoming the obstacles. This report will introduce the modified robot design from the previous design and the working principle on overcoming the obstacle and capturing the image of the cable.

b) Problem Statement

Human safety will be the top priority when it is related to engineering –technical areas as well as any other job or task related to human. There are many reported case where a technician of an electric cable maintenance team died while working on this power line. This occur in different ways such as electrical shock and falling to the ground while inspecting or repairing the electric cable. One of the solution for this problem is developing a robot which can help human as well as replace human force by a robotic system. There are many robot that can move along the suspended cable and overcome obstacle, but not much of it can capture the image of the defective cable. Thus, a robotic system with an ability to move along the cable, overcome the obstacle as well as capture the image of the cable need to be developed with the simplest structural design in order to help human in this related task of cable repairing and inspection.

c) Research Objectives

The aim of this research is to design and develop an electric cable inspection robot that can move along a cable, overcome the obstacles and capturing the image of the cables.

The objectives set is justified the aim are as follows:-

i. To develop an autonomous robot that will be able to navigate along electric cables avoiding obstacles.
ii. To equip the robot with camera to capture defects of wire.
iii. To evaluate performance of the robot

Author α σ ρ χ ν: *Department of Mechatronics Engineering, International Islamic University Malaysia, Kuala-Lumpur, MALAYSIA.*
e-mails: nasir.u@live.iium.edu.my, engnasirbd@yahoo.com, engnasirbd@gmail.com, md.n.uddin@ieee.org
Author Ѡ ¥ §: *Department of Electrical & Electronics Engineering, ADUST, BUET, I&E, Dhaka, BANGLADESH.*

d) Research Methodolgoy

In order to achieve the objectives and the target of the research, some steps and procedure are need to be taken into consideration. First and foremost, the topics of the research was studied through the previous research papers, journals, websites and other different type of books that related to this research. This is to make sure that the basic concepts about the design is adapted and the new design can be develop based on the previous and current design that available nowadays. Then, some important facts and concepts from the previous research have been rephrased in the literature review of this report. After that, the brainstorming of the idea and design are drafted based on the previous design that have been developed by the previous student and researchers. During the drafting stages, several design have been purposed for this robot. Some of it are rejected due to the unbalanced condition of the design. The design are constructed by sketching manually on the paper and then constructed by using Computer Aided Design (CAD) software. The designs are then divided into several subsystems. Here, it is divided into three subsystems which is mechanical part, electrical part and software part. The crucial part of the design is to choose the suitable components and devices that required in order for this robot to functions well at the end of this research. This system must be modeled in order for it to achieve its research objectives. Finally, the systems are being analyzed by using several calculation especially for the stability of the robot while moving along the cable as well as while overcoming the obstacles. Then, the documentation of the whole research are being done for the reference in future developments.

e) Project Outline

This report consists of six chapters. In chapter 1, there are the overview of the study, problem statements, research objectives and methodology as well as the project outline. In chapter 2, other researchers design and research have been discussed and compiled in the literature review part. Then, in chapter 3, the design of the system are drafted and it is divided into three major subsystems which is mechanical part, electrical part and software part. At the end of this chapter, the bills of materials has been tabulated for the budget reviewing and design implementation. The selection of component that required for this robot also being discussed and selected in this chapter. Chapter 4 will show the analysis of the design and some working principle flowcharts on how the system works and being controlled. The last chapter which is chapter 5 will be the conclusions of the research and the references used for this report.

Chapter 2

II. Literature Review

a) Introduction

In this part, some of the literature studies from the previous and current researchers are being presented. These include some types of publications such as articls, journals, conferences and other related resources that available which is related to this thesis. The discussion will be started with the comparison of different types of electric cable inspection robot that has been developed by the previous researchers. After that, the discussion will be summarize the advantages and disadvantages of the design that being implemented on the current robots. Then, this chapter will end up with a conclusion made based on the literature studies.

b) Electric Cable Inspection Robot And Cable Climbing Robot

Nowadays, there are several kind of electric cable inspection robot that has been developed by the engineers. This type f robot are able to help human in doing the various king of inspections and maintenances of the electric transmission power lines. With the emergence of this robot, the maintenance of the power lines can be easily to maintain and observe. This robot are programmed to do the same task that the power lines maintenance workers did. By using this robotic system, the precision and evaluations of the faulty of the cable can be increased as compared by using human power. Moreover, the electric cable inspection robot is one of the cable climbing robot. Most of the electric cable inspection robot can climb and move along an electric cable. This robot also can overcomes several obstacles that found along the cable. Therefore, several type of electric cable inspection robot and cable climbing robot such as Expliner, LineScout, SkySweeper and Robonwire are being discussed in the next section of this subsection.

i. Expliner (A Cable Inspection Robot)

Expliner is one of the sophisticated design that has beaten most of the previous machines that has been developd before it. Expliner was developed primarily as a robot to inspect live line and able to perform detailed inspection in up to four cables as well as the enouch mobility to overcome any obstacles that it faced. Expliner was manufactured and developed by HiBot Corporation in Tokyo, Japan. Expliner can performs visual inspections of cables, conductors, spacers and any other components on the electric cables with the equipped camera on board.

The concept of this design employs pulley to move on the transmission lines and has a carbon-fiber structure with a T-shaped based and a 2-DOF manipulator. Expliner can be actively controls its posture and overcomes the obstacles by moving its center of mass. This is performed by moving it counter-weight to front or rear side based on where it want to moves. The counter-weight must be placed as far as possible from the base of the manipulator in order to maximize its influence over the position of the center mass of the robot. This robot also can acquired image from the entire surface of the cable with two CCD mini-camera and mirror assembly attached on it. Besides acquired an image, it can also determine and calculate the diameter of the cable by using the laser emitter and receiver located with the robot.

Furthermore, Expliner also have consist a sensing units that connected on its compliant arms to allow the robot to balance itself and to make sure that the robot are not swinging when doing its preferred tasks. One of the safety aspect that is performed in this robot is the safety hook system. This safety hooks are installed under the pulleys of Expliner. The hooks will lock the pulley and the cable together without touching the cable. If there are the disturbances from the winds for example. Expliner will still safe with the safety hook locked. Moreover, the safety of the attitude of Expliner also constantly monitored. When the robots swing at a certain angle, a warning message will displayed and informing the operator that it is unsafe to continue the operation. The failure of the control system also being overcome by using a parallel microcontrollers which will be automatically activated when the main microcontroller fails.

ii. *Linescout (Electric Cable Inspection And Maintenance Robot)*

A LineScout robot are quite similar to the Expliner but differ in their theory of operations. A LineScout was developed by Hydro-Quebec's research institute which is the one of the leading technologies in the area of applied robotics, as it has been successfully deployed in the field for the live-line teleoperated inspection and maintenance. This type of robot can various kind of inspections such as visual inspections of the power line as well as doing the maintenance of the power line. Similar like the Expliner, LineScout also equipped with camera but it has extra two cameas that the Expliner. Two of the camera are mounted on the gripper arms while the other one is mounted between the wheels of the robot with the pan and tilt functions which provide the adjustable point of view. The images that the camera transmitted are most important as they used it as a feedback on the ground to drive different axes of movement.

Besides that, in order for the Lines Scout robot to move efficiently and fairly quickly along parts of spans with no obstacles, two-wheel design was chosen for this robot. Furthermore, it also have its own obstacles avoidance scheme as show in Figure 2.6. This avoidance scheme involves several clamps, a slide and some actuators to remove the drive pulleys from the conductor. By sliding its clamps and grabbing the power line, the robot is able to release its pulleys from the power line and slide over to the other side of the obstacles.

Apart from that , LineScout equipped with an onboard video card which enable it to receive a signal from up to four cameras and then transmits a combination of any two images either in "pictures on picture mode" or "split screen mode". This are very useful by combining the two wide-angle camera images since it allows viewing the grippers on both side of the obstacle simultaneously. The Line Scout also have a god telecommunications design. This robot can be controlled within a 5km wireless control range. The video feed, controls and sensor data are mainly communicated by using the radio connection. The Line Scout also have many tools that can be used for the maintenance of the power line cable. The camera and the robot can be controlled with the joysticks from the ground. Even though the Line Scout is fairly complex, but its control system are simple, intuitive and also ergonomic in design.

iii. *Skyseeper (A Low Dof, Dynamic High Wire Robot)*

SkySweeper is one type of a mobile robot designed to operate in the environment same as the Expliner and LineScout robot. This robot comprised of two links that is pivotally connected at one end. At this joint, a series of elastic actuator can actuate a relative rotation between two links of the robot. Actuated three-position clamp is located at the opposite end of each link. The clamp of the robot can be either open partially closed or fully closed. This robot can locomote on the cable in various ways by actuating the elbow joint and cleverly choosing the positions of the clamp.

This robot symmetrically comprised of two links of equal length which are pivotally connected with a rotary series elastic actuator (SEA) at the end. This SEA contains of a motor and a torsion spring connected in series. Motor housing is connected to the first link meanwhile the motor shaft is connected to one end of the spring. The other end of the spring is connected to the second link. This robots may have different kind of clamp positions which is open clamp, rolling clamp and pivoting clam position. By appropriately combining the actuation of the elbow SEA and the clamps, several modes of locomotion are possible to be achieved such as inchworm locomotion, swing and roll locomotion, swing –up locomotion and back flip locomotion.

Sky Sweeper have the disability to overcome the obstacles. This robot can only locomote along the cable. Then, this robot alos cannot have a camera that can be place on it. If there is the camera, it will not give a clear viw of the image that it captured due to the vibrations occurs while it's moving along the cable. Due to this disadvantages, this robot still need to be developed by the researchers and engineers in future.

iv. *Robonwire (Low-Cost, Lightweight Powerline Inspection Robot)*

Robonwire (Robot on wire) is a robot that designed to perform a tasks while moving on a cable. This robot can operate autonomously or being controlled by the remote which makes this robot is attractive for the inspection and maintenance of the powerline. This robot is lightweight and developed by using a low-cost budget. The Robonwire is equipped with wheels and arm mechanisms for locomotion and obstacles avoidance. The robot avoid the obstacle by retracting and engaging its arms sequentially. Robonwire consists of a base frame on which three arms are mounted.

The arm of the Robonwire is designed as a modular unit. The arm are designed to mount the wheels on the line without any coupling or claw mechanisms. Each of the arm are divided into three parts which is the base bracket, arm body and the wheel mount. The base bracket is mounted onto the base frame and connected to the arm body through a joint (Lower joint). Meanwhile the arm body is the main part of the arm and carries a wheel mount at its top through a joint (Upper joint).

This Robonwire come with some safety features. It has a safety clamp in each arms. The clamps is responsible for securing the robot to the line. Two powition of the servo determines the strength of the clamping. For example, the position of the servo may be heightened when gripping the line during obstacles avoidance. This clamp is essential to prevent the robot from tilting from the line or losing the grip. The obstacles avoidance methodology is quite similar to the LineScout robot. This robot is designed to detach the arm closest to the obstacles. Then the arm will fold underneath the robot to maintain the center of gravity of the robot. Two wheel will move the robot until the first arm crossed the obstacles. This steps will be rotated by the robot for the next arm until all arms have crossed the obstacles.

c) Conclusion

From the literature review, it can be conclude that many research has been done by researchers around the world in order to helps human in doing the electric cable inspection and maintenance jobs. Several prototype have been developed and some of it are now commercialize for this maintenance and inspection jobs. However, all of this research are develop by using a big amount of budget due to the demand from the power line inspection and maintenance company. So, in this report the approach taken are to build and develop a simple system with the implementation of mechatronics system with low –cost budget but reliable in doing the same operation as the previous researchers had done. Therefore, the prototype that will build must be able to overcome the obstacles as well as to capture the images and able to move along a cable without toppled down or tilt down from the cable.

Chapter 3

III. System Design

a) Basic Overview Of The Project

The main objective of this project is to develop a robotic system that can move along suspended cables like electric power lines. This robot must be able to overcome the obstacle such as electric poles, cable suspender, cable spacer and other obstacles that available along the cable. This robot will only use one cable to travel along it. Then the camera attach to this robot will capture the image and video feed of the cable and transmit it to the monitor. The design is recommended to use the simplest structure. The conceptual design of the robot is shown in Figure 3.1.

b) Purposed Designs

In this section, the design of the robot is being discussed and drafted properly. The design are divided into several mechanisms such as the branch arm, the robot body and the locking mechanism to attach the left and right part together.

i. *Branch Arm Mechanisms*

♦ Overview of the mechanisms

This mechanisms is the main part of the robot because this part will determine the ability of the robot to move along the cable as well as to overcome the obstacles along the cable either in stable condition or it will be toppled sown. Without this mechanism, the robot cannot overcome the obstacles.

♦ Proposed design of the body arm:

- Linear/ Rectangular branch arm:

This type of arm is the easiest type of arm that can be done. This is because it just only one item to make this arm. This branch arm will be attach together with the robot body and the RC servo motor that will lift – up the arm when avoiding the obstacles. This type of arm need to have additional counterweight for it to balance on left and right side of the robot.

- 45° slanted branch arm:

This type of arm is 45° slanted from the linear arm. This reason why it is slanted at 45°to make the body of the robot balanced on the left and right side. Thus ,the center of the gravity will be focused on one point of action. As liner branch arm, this arm will be place on the same location as the linear one.

♦ Selected design:

From the design discussed above, I choose the 45° slanted branch arm to be developed and put together on my prototype. This is because of the ability for the arm to locate the center of gravity on one point of action. Thus, four of this branch need to be on the prototype to achieve the desired objective.

ii. *Robot Body Shape*

♦ Overview of the shape

In the planned design for the prototype that will be constructed, the shape of the robot body need to be balanced on both side of the wings. Due to that, a minimized design of the robot body are required in order for it to achieve the objective. This body need to be light and have only few part that need to be attached together by screw or glue or other fastener. Therefore, this robot can balanced itself on the left on the left and right wings.

♦ Proposed design of the body arm:

- Rectangular-Shaped Body

This shaped is the commonly used on most robot. This type of shape need to be screw and fastens together in order for it to achieve the desired shape. Like the previous design of this robot, the robot body is made by using this type of shape. Due to that, it is not able to balance well while moving along the cable due to the screw used to attach the wall of the robot body together.

- Cylindrical-Shaped Body

This shaped is easy to be constructed for the body of the robot. This is because, this shape can be done using a pipe. we can find the bigger diameter of the pipe in order to balance both side of the robot. With this implementation, there are no screw or glue that are being used together to make the robot body. From that, the weight of the robot can be reduced and it can make the robot to be stable on both sides.

♦ Selected design

From the design discussed above, the prototype of the robot will used the cylindrical-shaped robot body. This is to ensure that the robot balanced on the left and right side and to make sure that the robot body are light enough. Due to that, the error of the joint and attachment of the rectangular-shape of the robot body design can be reduced.

iii. *Lock Mechanisms Of The Branch Arm*

♦ Overview of the lock mechanisms

The need of the lock mechanisms on the branch arm is crucial because the robot is developed using two wings which is left and right side. This two side of the robot will attach together by using the branch arm of the robot. At the end of this branch, there will be a lock mechanisms that attach the left and right side of the robot together. This lock mechanisms is important for the robot. If the lock mechanisms is not located at that point, the robot will swing to the left and right side while moving along the cable.

♦ Proposed design of the lock mechanism:

- Using electromagnet

This type of design was being done on the previous robot. At the end of the branch arm, an electromagnet mechanism is placed in order to be lock the left and right side of the robot. By using this type of mechanism, it will required more power to the robot due to the electromagnetic field that need to be created for this lock. Due to that, this lock become hot and might damage the robot.

- "Door-like" lock mechanism

This type of design look alike the door lock mechanism. This mechanism only allow one direction of movement due to the shaped of the lock itself. As we can see on the door lock mechanism, when we closed the door, the door handle need to be pulled or pushed in order to unlock the door. Thus, this type of mechanism can be applied on this robot to attach the left and right side of the robot together. This mechanisms will be used with the micro servo motor in order to unlock this locking system.

♦ Selected design:

From the design discussed above, the prototype of the robot will used the "door-like" lock mechanisms. This type of lock is easier to be constructed and will consume less power from the power source. Thus, both side of the robot can easily being lock and unlock using this type of mechanisms.

c) *Finalized Approved Design*

After discover the purposed design for this robot, the design of this robot is finally being done. All of the mechanism that discussed at the previous chapter has been implemented in designing the robot.

i. Cad Design (Picture)

ii. Dimension Of The Design (Picture)

iii. Part Names (Icture)

iv. Front, Top, Side & Isometric View (Picture)

d) *Components Selection*

i. *Basic Overview Of Component Use*

From the design that has been created as the previous chapter, this prototype required several components to make this prototype functions as desired. In this chapter, the selection of the components that will be used for this prototype will be discussed. This discussion will start from the controller selection of this robot, motor selection, sensors and other related components.

a. *Arduino Mega*

♦ Description:

- This board features additional SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that alow the shields to adapt to the voltage provided from the board.
- The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and over current. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the

fuse will automatically break the connection until the short or overload is removed.

- The Arduino Mega is a microcontroller board based on the ATmega1280/2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal OScillator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove, Diecimila or Uno.

♦ Specifications:

• Microcontroller	ATmega2560
• Operating Voltage	5V
• Input Voltage (recommended)	7-12V
• Digital I/O pins	54 (of which 14 provide PWM output)
• Analog Input Pins	16
• DC Current per I/O Pin	40 mA
• DC Current for 3.3V Pin	50 mA
• Flash Memory	256 KB of which 8 KB used by bootloader
• SRAM	8KB
• EEPROM	4 KB
• Clock Speed	16 MHz

♦ Use in this project:

Arduino mega will be used as controller for left and right part of the robot. The reason why Arduino mega is used to this robot because each part of the robot need at least 6 PWM output pin to control two servo motor (for branch open and close). One micro metal gearmotor (for robot movement on the cable), one servo motor (for actuator as a balancer) and two micro servo motor (for the branch arm lock and unclock). Therefore, Arduino Mega which has 14 PWM output are more than enough as this robot only need 12 PWM output.

b. *Rc Servo Motor*

♦ Description:

Servomotor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback, through a reduction gearbox. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing. Inside a typical RC servo contains a small motor and gearbox to do the work, a potentiometer to measure the position of the output gear and an electronic circuit that controls the motor to make the output gear move to the desired position. Because all of these components are packaged into a compact, low –cost unit, RC servos are great actuators for robots.

♦ Specifications:

• Dimension	40.2mmx19.8mmx36.0mm
• Weight	38.0g
• Torque	6kg/cm(4.8V),7kg/cm(6.0V)
• Speed	0.19sec/60degree(4.8V) 0.16sec/60degree (6.0V)
• Operating Voltage	4.8V-6.0V
• OperatingFrequency	50.0Hz
• Moving Range	0° - 180°
• Pulse Width Range	0.5ms-2.5ms
• Gear Material	Plastic

♦ Calculation of maximum load torque:

The mass of micro metal gearmotor or electromagnetic system which placed at the end of the branch arm and the weight of the branch itself cannot be more than this maximum allowable mass which is 0.4667kg

c. *Rc Micro Servo Motor*

♦ Description:

Servomotor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for osition feedback, through a reduction gearbox. This RC micro servo motor is tiny and lightweight with high output power. Inside a typical RC micro servo motor contains a small motor and gearbox to do the work, a potentiometer to measure the position of the output gear and an electronic circuit that controls the motor to make the output gear move to the desired position. Because all of these components are packaged into a compact, low-cost unit, RC servos are great actuators for robots.

♦ Specifications:

- Dimension — 22.2mm x 11.8mm x 31.0mm
- Weight — 9.0g
- Torque — 1.8kg/cm (4.8V)
- Speed — 0.1sec/60degree (4.8V)
- Operating Voltage — 4.8V
- Operating Frequency — 50.0Hz
- Moving Range — 0° - 180°
- Dead Band Width — 10μs
- Gear Material — Plastic

♦ Use in this project

Micro metal gearmotor will be used as driver for robot to move along the cable. Lowest angular speed (rpm) of micro DC motor has been chosen to provide greater torque during movement along the cable.

d. *Micro Metal Gearmotor*

♦ Description:

Micro metal gearmotor provides enough torque with combination of gears. It is suitable for small size robot.

♦ Specifications:

- DC — 6V
- Gear ratio — 298:1
- Stall Current — 360mA
- Stall Torgue — 1.8kgcm
- Weight — 10g
- Free-run (rpm) — 45
- Freerun(current) — 30mA

♦ Calculation

e. *Tilt Sensor Module*

♦ Description:

Tilt sensor module is a sensor that will detect the movement of the object either it is tilted or not. This sensor is a ball rolling type sensor. The module will output logic LOW when the module is not tilted until the threshold angle and it will output logic HICH when it is tilted over the threshold angle. The tilt angle for this sensor is from 45 degree to 130 degree.

♦ Specifications:

- Operatingvoltage : 3.3 to 5VDC
- PIN : VCC=5V,GND=0V,DO=digital output from module

♦ Use in this project:

Tilt sensor module is used in this robot to detect the orientation of the robot. When the robot is tilt, this sensor will activate the balancer located at the bottom of the robot body to stabilize the robot.

f. *Ultrasonic Ranging Module*

♦ Description:

The Ultrasonic module detects the distance of the closest object in front of the sensor (from 2 cm up to 400cm). It works by sending out a burst of ultrasound and listening for the echo when it bounces off of an object.

♦ Specifications:

- Operating voltage — +5V
- Static current — less than 2mA
- Detectionangle — Not greater than 15°
- Range — 2cm~400cm
- Precision — 0.3cm

♦ Use in this project:

Ultrasonic sensor is use in this prototype to detect the obstacle which this robot need to overcome it. When the obstacle is detected within specific range, this sensor will trigger the roller driver to stop and the branch arm lock to unlock. Then the servo motor located at the branch arm will activated and lift-up the branch arm.

g. *Camera Module*

♦ Description:

The webcam is the easy to used camera which we can only plug-and-play the camera as we desired.

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This camera will provide enough resolution for image and video that will be recorded.

- Specifications:
  - Video capture: Up to1024x768pixels
  - Logitech Fluid Crystal™ Technology3*
  - Photos:Up to 5 megapixels (software enhanced)
  - Built –in mic with noise reduction
  - Hi-speed USB 2.0certified (recommended)
  - Universal clip fits laptops, LCD or CRT monitors
- Use in this project:

This webcam is used for the image capture and video recording of the cable during the inspection of the cable is done. This camera must be able to capture enough resolution of the cable to inspect the aulty that may occurs on the cable. Note that, this type of camera are subject to change with respect to the size of the robot and cost of the camera module.

e) Estimated Budget

No	Component	Quantity	Unit Price (RM)	Total Price
1.	Arduino Mega 2560 R3	1	77.50	77.50
2.	298:1 Micro Metal Gearmotor	2	35.00	70.00
3.	RC Servo Motor (C40R)	4	49.00	196.00
4.	RC Micro Servo Motor (SG90)	4	10.80	43.20
5.	Ultrasonic Ranging Module	4	10.90	43.60
6.	Tilt Sensor Module	2	13.00	26.00
7.	Camera Module	2	50.00	100.00
8.	Bread board 85mm x 55mm x10mm	2	7.90	15.80
9.	Male to Female Jumper Wires, 40pcs	2	6.80	13.60
10.	Male to Male jumper Wires, 60pcs	2	6.80	13.60
11.	IR Transmitter & Receiver	1	3.00	3.00

Chapter 4

IV. Design Analysis

a) *Introduction*

In this chapter, the design proposed in chapter 3 will be analyzed. The analysis will consist of the design dimension, component placement on the robot, communication between the components, the microcontroller scheme and the working principle of the robot.

b) *Design Dimension*

The dimension of the robot is already described in chapter 3. This dimension is subject to change depending on the size of the component that will be used when constructing the robot.

c) *Component Placement*

From the design, it can clearly see that the component will be placed mostly on the body and the arm of the branch of the robot. After all the component is placed on its position, one counterweight will be place on top of the body to make the robot stable. If the robot is stable enough after putting all the component at its desired location, no counterweight will be used for this robot.

d) *Attachment Of The Robot*

As we can see in figure, the body of the robot is actually separated into two parts which is left and right part. This two part of the robot will be attached together by using the door-lock mechanisms that located on top of the body. The mechanisms is attach with the branch arm of the robot. The branch of the robot will be lifted-up one by one when avoiding the obstacles. The working principle of this mechanisms can be seen with the working principle flowchart provided in next section of this chapter.

e) *Communication Between The Components*

In this robot, only one microcontroller will be used and place on the robot. As we can see in figure, all the component are placed in its desired location. Each of the component is related to each other. In other words, each component need to communicate between another components. In this robot, servo motor of the branch arm will communicate with the ultrasonic sensor as well as the micro metal gearmotor and micro servo motor while overcoming the obstacles. While moving on the cable, the micro metal gearmotor will communicate with the ultrasonic sensor as well as the tilt sensor. Therefore, to communicate between all the components, the used of microcontroller which is Arduino Mega is required. With this microcontroller, all the component, all the component can know the sequence of their movement and their time when the component is required and when the component are not required in each of the movement. This can be clearly seen on the working principle flowchart and the microcontroller unit scheme in next section of this chapter.

f) *Working Principle Flowchart*

Working principle flowchart of the robot has been constructed as shown in the next section of this chapter. This flowchart shows how the microprocessor will be programmed in order for the robot to functions as desired.

i. *Overview Of The Working Principle*

The robot will move along the cable by using its roller. This roller will be driven by a micro metal gearmotor attached together with it. This motor can move forward and backward. When the ultrasonic sensor detect certain range of distance, the MCU will transmit the command to the RC servo motor and the micro and the micro servo motor. The micro servo motor will unlock the lock and the RC servo motor will lifted-up the branch arm. Then, the driven roller will move forward to overcome the obstacle. After the first branch arm crossed the obstacle, the RC servo motor will then lifted-down. The roller of the first branch arm will stay on the cable and the lock of the arm is activated. Then, the second branch arm will follow the same step as the first branch arm. It will continue until all the branch arm crossed the obstacles. During the movement of the robot along the cable and during the obstacle avoidance, the tilt sensor will be activated . This sensor will triggered the RC servo motor of the balancer at the bottom of the robot body to move forward or backward in order to stabilize the robot. If the robot is not tilt, the RC servo motor of the balancer will remain at its current position.

ii. *Working Principle Flowchart For Obstacles Avoidance*

As shown in Figure 4.4

iii. *Working Principle Flowchart For Robot Balancing*

As shown in Figure 4.5

iv. Working Principle Flowchart For Camera

As shown in Figure 4.6

g) *Graphical View For Obstacls Avoidance Scheme*

Chapter 5

V. Conclusion and Recommendations

a) *Conclusion*

After all the research done, finally I manage to construct one design of the electric cable inspection robot. In designing this prototype, all the knowledge that related to this type of robot are applied. This robot is able to overcome the obstacles that found along the cable as well as to capture the image of the cable during the movement along the cable. Therefore, this design of the robot will be implemented in the next progress of this project which is to build the prototype of this design. This implementation will be done in the next semester together with the performance evaluation of the robot. Hopefully this project will achieved its objectives successfully and become the beneficial references for other in future.

b) *Recommendations*

- ♦ Use a lightweight item to ensure the motor can perform the actions required perfectly.
- ♦ This robot can be protected from the electrical shock by using suitable insulator around the body of the robot.
- ♦ Make sure the microcontroller are using a parallel network in order for it to functions well if there are unexpected disturbance of electricity or power sources and other electrical components.
- ♦ To balance the robot, we can used other type of actuator as well as other type of sensor that suitable with the size and budget of the robot.

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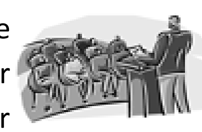

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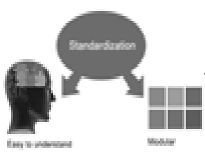

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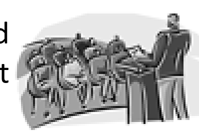

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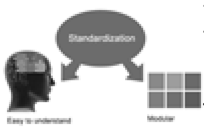

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Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

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(Free of charge) from the following website:

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

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This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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ISSN 9755861