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Lecture Notes on Data Engineering and Communications Technologies 31

A. Pasumpon Pandian
Tomonobu Senjyu
Syed Mohammed Shamsul Islam
Haoxiang Wang *Editors*

Proceeding of the International Conference on Computer Networks, Big Data and IoT (ICCBI - 2018)

Springer

Lecture Notes on Data Engineering and Communications Technologies

Volume 31

Series Editor

Fatos Xhafa, Technical University of Catalonia, Barcelona, Spain

The aim of the book series is to present cutting edge engineering approaches to data technologies and communications. It will publish latest advances on the engineering task of building and deploying distributed, scalable and reliable data infrastructures and communication systems.

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Contagious Diseases Prediction in Healthcare Over Big Data

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Abstract. As Data trends go higher and higher, the data creation process tends to increase at an unprecedented rate. They are not only increasing, they also change, and incarnate from one form to the another. Recently, Big data revolution has introduced an incarnation of how the data is captured, accessed, aggregated, converted and stored. Healthcare communities is one of the big data procreations, where data gets generated rapidly. The appropriate analysis of healthcare data helps to detect the diseases at an early stage to save the patients' life. Although, analysis is required to make a proper decision, this analysis is declined due to the incomplete data. This paper focuses on the prediction towards the emerging contagious diseases to provide enhanced accuracy in the process of disease detection. To solve the incomplete e.g. missing data, the Improved Expectation Maximization (IEM) has been employed. Here, the experiment is carried out on Ebola disease. This research work proposed a new Ensemble Neural Network algorithm using structured and unstructured data. A proposed model was trained on prediction from dataset and evaluate each model. In this work, the Ensemble Neural Network shows an average performance, but leverages a very firm and more consistent performance analysis accuracy. This method will deliver an enhanced potential for the decision makers in healthcare communities.

Keywords: Big data analytics · Ebola disease · Healthcare · Expectation Maximization · Neural network

1 Introduction

Ebola Virus diseases (EVD) are primarily handed down from wild animal to humans, and the transmission growth in population occurs through human to human transfer. People commitment emerges as the significant component to help the healthcare practitioners to promptly identify the humans who are under the contagious disease. Quick and fast notification is very important in order to provide a quick helping hand. Hence, it needs significant attention when early symptoms are detected to restore the fluid into a patient. Despite the hype, the treatment also has some challenges like unauthorized way of treatment and suggestions. However, diverse number of treatment based on immunology are still under trial, and other drug combinations are under developmental stage. Also there have been a lot of cases and deaths during this irruption. The contagious diseases are found in Africa countries such Guinea, and it is

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moved to its borders namely Sierra Leone and Liberia. The virus family includes 3 classes: Cuevavirus, Marburgvirus, and Ebolavirus. Inside Ebolavirus class there are 5 species which are identified in different parts of Africa such as central, north and south. The Ebola virus is considered as the notable outbreak in the continent of Africa. Early detection and warning of outbreaks will emerge as a life saver resource. To achieve this work, an ensemble neural network based on internet of things could play a key role to fight against EVD.

2 Related Works

İnfectious disease is emerging as a threatening fatal disease to the human community. The world health organization (WHO) invests all efforts to support different policies that includes systems which are willing to help to investigate outbreak at early warning [1]. An observation of any unknown disease such as haemorrhagic fever might be reported by nurses and other people who are involved in healthcare profession, this report will leverage an early detection as well as prevention. There is an uplift in strategies of early detection system [2, 3], however some policies of investigations are not on normal references [4], those changes are caused by a lack of past epidemic records and agreement based on the occurence of it [5], for this absences of old records, the early detection warning (EDW) was introduced and implemented in order to store the previous data. The other means of detecting the epidemic diseases are mobile health (mHealth) devices, which is utilized globally. The primary purpose of devices used in healthcare is to record all the information related to the patient. After first step of recording, the next step is to confirm whether the disease exist or not, it is done by using rapid diagnostics assay rest (RDAT). The above mentioned steps help to save a life before the diseased person reaches the critical condition [7]. The detection process can be enhanced when analysis is automated [8]. Besides, [9] has compared the bioinsipired techniques, where its main purpose is to measure the performance of heterogenous telemedicine transportation, massive information are transported using mobile health devices. [10, 11] planned another way to transport the health records in a better way based on the observance. [12] has carried the work of heterogenous systems, and to study the steps of analysis has been reduced in order to decrease the medical expense. [13] telehealth system has been developed to regulate the rules and to design knowledge from the obtained personal health record (PHR). [14] an advanced application was developed to effectively deal with massive healthcare data. [15] planned to associate best massive data sharing rule to deal with complex healthcare information. This work, develops a system that has six applications with an ability to identify the unsound patients. To secure e-health data, a proposal system [16] was developed along with a capacity to predict the emerging health risk. Prediction and victimization of ancient unwellness risk models sometimes involve a machine learning rule which need a labeled class e.g. supervised learning. [17, 18] within it all datasets are splitted into two classes either unsound health or sound health. İn clinical fields, these models are needed to increase the healthcare performance [19, 20]. There is a need of early detection and early warning of epidemic. When these two earlies are certained, the lives of many humans will be saved. [22] describes the research work based on the

multimodal disease prediction using ensemble neural network. In [23] malaria disease has been predicted with the help of ant colony and random forest tree methodologies.

3 Proposed Methods

3.1 Likelihood

There are variety of methods used to deal with the missing data values. In this work, the proposed method determines the knowledge of the sampled data which are drawn from different variables, and these variables are then compared with the existing variables. With this comparison, the desired parameters can be calculated based on the mistreatment of the present knowledge. In case of the absence of knowledge from variables, the next step is to calculate the estimated missing variable. The outcome shows the linkup among variables which are counted as mistreating. This missing knowledge can also be identified during the distribution of the different variables.

3.2 Improved Expectation Maximation

Improved Expectation Maximization (IEM) may be a variety of the utmost chance methodology which will be accustomed to produce a brand new knowledge set, within which all the missing values are imputed with values that remains calculable by the utmost chance strategies [21].

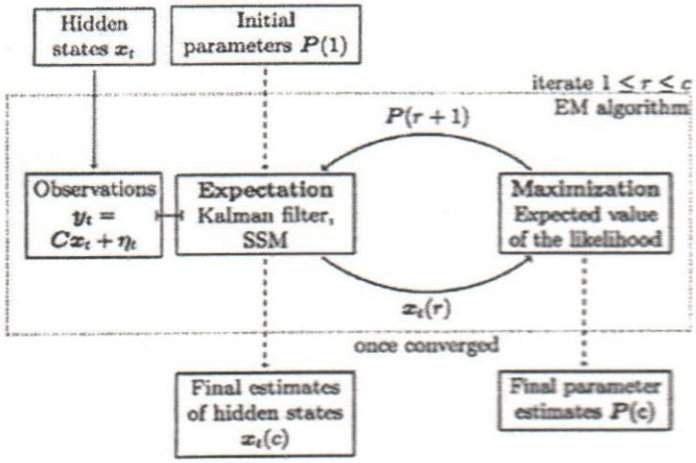

Fig. 1. Expected maximization (source. 1)

This work will provide the best output from the deviation of expected parameter which are primarily determined to possess a high degree of positiveness of the expectation and may underestimate the quality error. Further, this work focuses on the

responsibility laid upon the Improved Expectation Maximization technique, an expected price that supports the variables present on the market for every case is substituted for the missing knowledge. As a result of that, one imputation omits the attainable variations among the multiple imputations, one imputation can tend to underestimate the quality errors and so overestimate the extent of exactness.

As the contagious diseases spread rapidly, we need a system which can iterate the process in fast manner. Thus Fig. 1 illustrates the process of EM algorithm, which has the ability to demonstrate the different stages of the proposed system.

3.3 Ensemble Neural Network

Ensemble classifier is a machine learning technique, which has been used to learn and recognize a complex pattern and draw a decision based on the available complex data. In this ensemble, it has the ability to describe a set of predetermined diseases which simultaneously enhances the accuracy. In this technique, the classifiers are combined for the primary aim of creating an enhanced model in order to increase the accuracy.

The above Fig. 2 demonstrates the process of dealing with contagious virus disease, where each case is first classified by the neural network, the suspected case and confirmed case, then they are grouped into different categories, both groups at the end where they are warned and treated if the virus is detected.

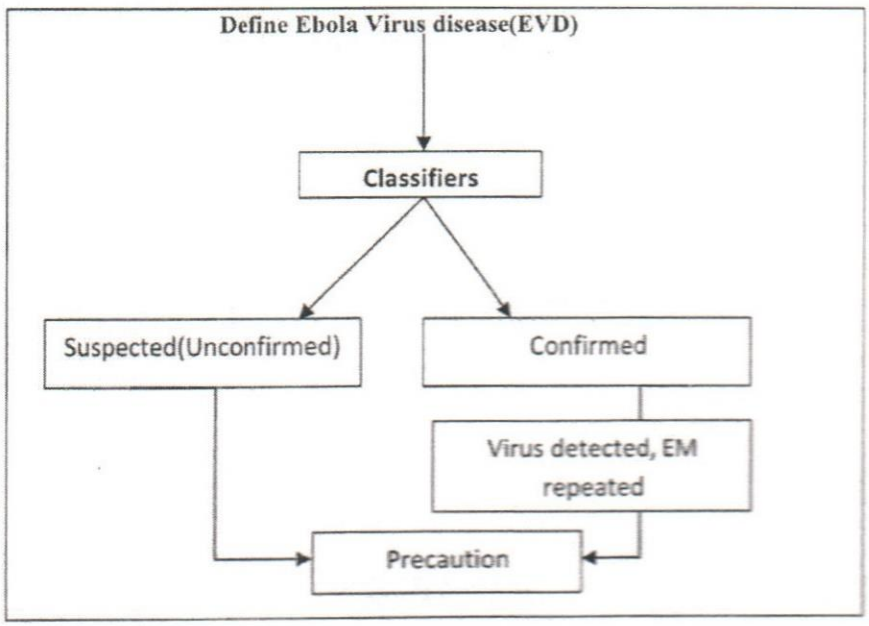

Fig. 2. Proposed system of ENN

4 Conclusion

This research work proposed a system to intelligently fight against contagious diseases. The system has been proposed based on the Expectation Maximization (EM) and Ensemble neural network (ENN). İt is believed that this system will provide a notable contribution to the area which is affected by the contagious diseases. Moreover the systems also need some enhancement to improve the prediction as well as the accuracy. This approach is mainly focused on solving the incomplete data present in big data analytics, and deals with continuos data using ENN. Furthermore, the proposed system also has the ability to benefit other healthcare communities.

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8 DEVELOPMENT OF NANOCOMPOSITE BIODEGRADABLE HYBRID POLYMER AS A NOVEL BIOPLASTIC

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ABSTRACT

In many agriculture-based countries, the main problem is to keep the fruits and vegetables safe and fresh until they reach the consumer's hands. To reduce this problem we have to go for an external coating agent or a biodegradable packaging material to increase the shelf life of the food. Biopolymers such as cellulose, starch have emerged as effective alternatives to plastic packaging materials, with desired packaging functionality and biodegradability. In this process, a hybrid nanocomposite film consisting of cellulose, starch, whey, glycerol, and aluminum oxide nanoparticles (Al2O3-NPs) by solution casting method was developed. Nano-Aluminum addition results in Enhanced mechanical properties and makes Alumina thermodynamically stable over a wide temperature range. Characterization and shelf-life study of the films indicated the uniform distribution of the components in the developed films. Experimental studies on the packaging of fruits and vegetables indicated that the shelf life of the fruits can be extended to one more week in the case of the hybrid biopolymer film compared to storage in normal polyethylene films.

KEYWORDS Agriculture, Bioplastic, Bioplymer, Nanocomposite and Polythene.

INTRODUCTION

Bio-plastics or biodegradable plastics are replacing the source of plastics that originated from polymers. Bio-plastics are now being manufactured from bio-based material like sugarcane, corn, sugar beet and cassava. These are material returns to its natural state when buried in the ground. The degradation of bioplastics depends on factors like temperature, moisture, and oxygen availability. The use of nanomaterials has been increasing for the past decade and they find large applications in food packaging.

Nanotechnology applications in food packaging can be divided into two different types: (i) improved packaging, where nanomaterials are mixed into the polymer matrix to improve the gas barrier properties such as polymer/clay nanocomposites; (ii) "active packaging", where the nanoparticles interact directly with the food or the environment to allow a better protection of the food, such as Al2O3-NPs as antimicrobial agents. Metal

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Foreword

In the context of human health, a large number of natural products have been collected, collated, characterized, and made available to mankind. Some of these products target the diseases, whereas others simply work for the rejuvenation of the body by their immunomodulatory actions. Yet another ones work beyond the human body and perhaps reach to the soul. Of all the plant-derived herbs, saffron has always attracted a great deal of attention of common man and elites alike. The actual saffron is the dried stigma of *Crocus sativus* L., family Iridaceae. A sizable part of the literature is devoted to describe its health potentials and beneficial effects on the human body. Although mind and body are connected, they still maintained functional compartmentalization. Saffron has very positive effects on a large number of vital systems of the human body encompassing central nervous, cardiovascular, digestive, locomotor, urogenital, ophthalmic, integumentary, and immune systems. Saffron's safranal is an aromatic aldehyde, a vital component of plant volatile oil. In addition, saffron has more than 150 different types of components. The present book on saffron truly reflects deep and wide understanding of the authors accumulating crucial fact about this much sought-after and wonderful gift of nature. I found the book unputdownable and sincerely hope that it would evoke a great deal of interest among people who respect nature and believe in naturopathy. I envisage that this book would prove to be an eye-opener to students, teachers, and researcher. I found that this book reflects deep scientific understanding and academic prowess of the editors, Maryam Sarwat and Sajida Sumaiya, who have complemented each other to bring about their very best on saffron.

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Contents

CHAPTER 19

The Remarkable Pharmacological Efficacy of Saffron Spice via Antioxidant, Immunomodulatory, and Antitumor Activities

HAMID A. BAKSHI • HAKKIM L. FARUCK • SANGILIMUTHU ALAGAR YADAV • MURTAZA M. TAMBUWALA

INTRODUCTION

Cancer is considered as the uncontrolled unnatural proliferation of cells in the human tissue system, which may end in fatality. Cells having abnormality with cancer are also called malignant; these cells naturally attack to kill the good cells. The birth of these cells is due to disequilibrium in the body, which can be handled by removing the disequilibrium, which would cure the cancer. Multimillion dollars are being spent yearly on cancer research, but still, the cause of cancer is far from our reach (Jemal et al., 2005). Several million people are new victims of this disease yearly and go on the verge of death. About 2%–3% deaths worldwide are due to cancer as per report published in 2006 by American Cancer Society. Owing to cancer, around 3500 million people are killed yearly in the world. Many chemical agents are used to cure the diseases, but the treatment leads to severe adverse effects, prohibiting the administration of these chemical agents (Kathiresan et al., 2006).

Cancer is considered as the world's second major cause of death. The main reasons for occurrence of the diseases are chewing of tobacco, smoking, imbalances in diet and hormones, and chronic inflammation (Ames et al., 1995). Worldwide breast cancer is considered to be widespread among women (Koduru et al., 2007). Among South-African women, about 3% of women are affected by breast cancer (Koduru et al., 2007). Further in line is the spread of colon cancer in the United States. Among US men, carcinoma of the prostate is widespread and identified with an estimate of around 0.2 million new cases and 37K deaths expected yearly, as per 1999 report of American Cancer Society. With increased longevity in India, the cancer disease is going to be a threat, as most common cancer in elderly is digestive tract cancer.

About 6% men and women are detected with gastrointestinal cancer at certain stage in their life in the United States. Many people are seeking alternative or complimentary line of treatment because of threat of death by cancer and severe side effects associated with chemotherapy and radiation therapy. The significant line of treatment for cancers include lifestyle changes such as dietary changes, avoiding of tobacco products, treating inflammation efficiently with intake of nutritional supplements to enhance immune response. Contemporary study is seeking solutions to find effective drugs for chemotherapy without any side effect having new horizons in understanding cell biology.

In current standard treatment system, chemotherapy is the most prominent option for advanced stages of cancer which leads to metastasis. However, cause serious side effects to normal tissues(Somkumar 2003; Pandey and Madhuri, 2006).

Traditional medicines from plants are being used since thousands of years all over the world for various ailments in human and animals. They cure ailments including cancer with no toxicity and not affecting the health and vitality of the patient. Around half of the contemporary drugs are from plant origin, and most of them have the capability to control spread of cancer cells (Rosangkima and Prasad, 2004). As per the World Health Organisation about four-fifth of the people in developing world opt for natural drugs of plant origin for their main source for cure. A contemporary study

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indicated more than 60% people rely on vitamins or herbs for their cancer cure (Madhuri and Pandey, 2008; Sivlokanathum et al., 2005).

Since a decade, natural drugs are being accepted world over and have made a difference in health as well as international trade of these herbal medicines.

This also made possible the world's large population to use these medicines and improve the health (Akerele, 1988). India is a major user of herbal medicines. The United States has also been using the plants and phytomedicines on large scale since last 2 decades. The United States has established a National Center for Complementary and Integrative Health (NCCIH). The natural herbal medicines are being used as diet supplements along with essential vitamins, amino acids, and minerals (Rao et al., 2004). Consuming natural herbal products is considered a routine for any ailment in the South-African cultural life. As per an estimate, about 27 million South Africans normally consume herbs from more than 1000 varieties of plants (Koduru et al., 2007; Meyer et al., 1996). Number of herbal products, world over, including India, are used from ancient times for cancer prevention and therapy. Select medicinal plants have been of interest to scientists for study of the natural products and for cure of carcinoma or tumor.

CHEMOPREVENTION

By avoiding the exposure to known carcinogens, cancer risk can be reduced, but many of the unknown carcinogens do exist, and it is difficult to avoid their exposure unless proper identifications are done. Moreover, the prevention of exposure to some of these compounds being used in daily life requires major lifestyle changes, which are difficult to achieve. Lifestyle modification alone can help prevent almost 66% cancer cases according to researchers. Doll and Petro (1981) indicated that about 10%–70% (mean 35%) cancers are associated to diet, based on the study of diseases in humans and statistical data, significantly covering the food items that enhance the risk. Although the exact number is ambiguous, there are numerous evidences from clinical, epidemiological, and laboratory research that confirm cancer risk to be associated to the dietary factors.

The contemporary study uses modified diets and nutritional supplements to prevent cancer. It is envisaged that people may need to consume exclusive pills or two, prepared from herbal products, to prevent or delay the outbreak of cancer (Greenwald, 1996). However, an appropriate study of the mechanisms and the constituents of fruit and vegetables help fight cancer is mandatory prior to recommendation for their inclusion in supplementary diet or prior to the clinical study.

Biologically active compounds known as phytochemicals are low-energy compounds in traditional natural diet that have significant anticarcinogenic and antimutagenic properties. Having known the large structural variations of phytochemicals, it is difficult to define structure–activity correlation to infer their basic molecular mechanisms. An improved technique would be to study their impact on cancer-related signal transduction pathways.

It has been indicated by studies that the risk of developing cancer in South East Asian population is far lower than those in North America and is attributed to the routine use of ingredients such as cruciferous vegetables, turmeric, cayenne, soy, garlic, and ginger in their diet, which work as chemoprevention.

Several studies have mentioned plant-based chemopreventive ingredients or compounds and their capabilities for prevention and control of cancer. Since these chemopreventive compounds are obtained from natural food products, they are considered safe pharmacologically. The content of these dietary ingredients are wide range of different compounds such as polyphenols from green tea, curcumin from turmeric, and organosulfur compounds from garlic (Sporn, 1976).

Cancer prevention, control, and management by these phytochemical compounds is recognized as accessible, acceptable, inexpensive, and readily applicable. Promoting the awareness to consume these natural phytochemicals for prevention and control of cancer would be appreciated, specially with rising cost of health care for people at large. Many natural components such as carbohydrates, fats, and proteins, as well as vitamins, minerals, and fibers from plants are under study for their use as cancer-preventive drugs. In spite of important advances in mechanism of understanding cancer spread, very little is known about cancer preventive agent's mechanism of action. The action of natural phytochemical drugs is likely to have a combination of many distinct chemopreventive mechanisms. Disturbance or irregularity of intracellular-signaling cascades leads to growth of cancer cell from healthy cells; hence, it is significant to understand chemical signaling mechanism and the network, which get affected by individual chemopreventive natural product to get improved idea of their basic mechanisms.

FREE RADICALS AND ANTIOXIDANTS

Toxic byproducts of oxygen metabolism are recognized as free radicals and are highly sensitive species. Ordinary function of cells such as ovulation or fertilization, mitochondrial respiratory chain, phagocytosis, and arachidonic acid metabolism may give rise to extremely reactive oxygen species (ROS). Increase in the formation of ROS has been seen in several pathophysiological

state. When cerebral tissue encounters noxious stimuli, they produce oxygen free radicals during recovery phase (Beal, 2000). Oxygen can immediately take unpaired electrons from organic species and convert them to partly reactive species, together they are called ROS, including oxide (O2), alkoxy (RO), peroxyl (ROO), hydrogen peroxide (H_2O_2), hydroxyl (HO), and (NO) nitric oxide till converted to water. Halliwell and Gtteridge (1999) reported that the majority of the free reactive species are developed in the mitochondrial as well as microsomal electron transport chain.

In mitochondrial respiratory chain, moderately ROS are retained by cytochrome oxidase. However, ubiquinone directly transfers electron to oxygen compared with retained moderately reduced species. Autooxidation of semiquinones may generate super oxide anion in the internal mitochondrial membrane. Mitochondrial electron transport chains are enzymatically dismutated to H_2O_2 for majority of superoxide radicals. The alkoxy and hydroxyl free radicals quickly attack the macromolecules inside cells being highly reactive (Hemnani and Parihar, 1998).

Lipids, enzymes, proteins, carbohydrates, and DNA in cells and tissues are damaged by free radicals, the ROS. ROS leads to protein modification and DNA damage, which leads to cell fatality because of DNA fragmentation, lipid peroxidation, and membrane damage. The damage due to oxidation by ROS includes the toxicity of xenobiotics as well as the pathophysiological leading to skin aging, cognitive dysfunction, atherosclerosis, diabetic retinopathy, abnormal growth of cells—neoplasm (benign or malignant), cataract, adult acute respiratory attack, organ failure, vital illness such as sepsis, shock, long lasting inflammation of the gastrointestinal tract, condition in which blood clots form throughout the body, disseminated intravascular coagulation (DIC), tissue injuries, deterioration of the immune system and its phagocytic cells, nitric oxide production by the endothelium, ischemia reperfusion injury leading to vascular damage and liberate copper and iron ions from metalloprotein (Boveris et al., 1972).

Deficiency of iron content leads to different neurodegeneration diseases such as amyotrophic lateral sclerosis, spastic paraplegia, gliosis and multiple sclerosi (Heinonen et al., 1998).

Antioxidant Activity

A significant role such as health protection is played by antioxidant compounds. The hazard for chronic ailments including cancer and cardiac disease is reduced by antioxidants as per scientific evidence. Fruits, vegetables, and whole grains are some of the main supplies of natural antioxidants. Substances which protect from oxidation, like phytate and phytoestrogens, phenolic acids, vitamin E, vitamin C, and carotenes, present in plant-sourced food are recognized to have the capability to reduce the cancer disease risk. Almost all antioxidant compounds derived from plant sources in a typical diet have different properties as well as physical and chemical characteristics.

The ability to nullify the free electron species is the main characteristic of antioxidants. Biological systems have harsh free radicals and oxygen species from several sources. The oxidation of proteins, nucleic acids, lipids or DNA by free radicals may initiate degeneration. Free radicals such as peroxide, hydroperoxide, and lipid peroxyl are scavenged by antioxidant compounds such as polyphenols, phenolic acids, and flavonoids for prevention of oxidation of cell components leading to degeneration. The antioxidants in fruits, red wine, tea, and vegetables have the efficacy of natural foods for reduction of the degenerative chronic diseases including cardiac ailments and cancers, according to a number of clinical studies. The literature mentions several studies about the free radical reduction properties of antioxidants in foods (Miller et al., 2000).

IMMUNOMODULATION ACTIVITY

The principal function of immunomodulator is to balance the immune system components by either regulation and suppression or stimulation and normalization. If pathogens or infectious chemicals attack and disturb balance of immune system and shift it into disease state, immune system activates and provides primary protection against such attacks. The starting point in immunomodulation is to hunt for natural chemicals that can cure residual cancer (Yamamoto, 1996). The adjuvant biological therapy results in the discovery of Bacillus Calmette Guerin (BCG) as an antituberculosis vaccination (Petard et al., 1998) and systematic utilization of levamisol (Kurman, 1993) proved to be quite promising. Most important advancement in immunomodulation is the discovery of cyclosporine (Walsh et al., 1992). For the prevention of graft rejection, it is used as a powerful immunosuppressant and is found to be a blessing for many. For the treatment of several autoimmune diseases, the cyclosporine is being used.

To increase the efficacy of vaccine, immunoadjuvants are used, because a specific adjuvant is used with particular vaccines, hence this could be considered as specialized immunostimulants. The major impediment in development of antimalarial vaccine was lack of a proper biological adjuvant (Allison, 1997).

Nonspecific immunostimulants were used to enhance the body immunity against disease. Immunostimulants can work with innate immune reaction and with adaptive immune action. For a normal individual, the immunostimulants are intended to serve as preventive or promoting immune reaction, i.e., immune potentiators, by enhancing the primary stage of immune reaction and for the individual having a poor immune reaction as immunotherapeutic drugs. For conditions such as autoimmune diseases, graft rejection, and quick immune response or delayed type of hypersensitivity, immunosuppressants might be used for their management.

There are many applications of immunomodulation as conformed by contemporary scientists.

In modern treatment, the aspect of immunomodulation viz. immunopotentiation is significant, when the host safeguarding systems are to be enhanced with a condition of poor immune reaction.

Indian Traditional Medicine called *Rasaynas* that deals with medicine from plants has gained attention of many researchers. Majority of the studies have been conducted irrespective of a significant interdisciplinary technique. References of several plants that have the immunomodulatory effect were found, and several of them are being studied by contemporary scientific methodologies and have these characteristics. These plants include *Aloe vera* (Gharila kumari), *Allium sativum* (Lasun), *Asparagus racemose* (Satawar), *Curcuma longa* (Haldi), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Giloe), and *Withania somnifera* (Ashvaganda).

ANTITUMOR ACTIVITY

The basic curative techniques for cancer are surgery and radiation, but these are most successful if the tumor is detected at an initial stage. For later stage of tumors, chemotherapy is chosen, and though these medicines are efficient, they have major adverse effects and drug resistance (Kelloff et al., 2000), hence new therapeutic alternatives are required. In the realm of alternate cancer medicines with very minor toxicity and low adverse effects, herbal Indian drugs are considered a good choice.

In the hunt for alternate antitumor agents, researchers put in efforts to find the suitable natural drugs for their efficacy in controlling cancer risks, delaying carcinogenesis, or preventing tumor development. Many plants such as *Taxus brevifolia* (Taxceae) which is a source of taxanes (paclitaxel and docetaxel), Pacific yew, *Digitalis purpurea* (Plantaginaceae), which are sources of digitalins, and purple foxglove have attracted researchers for their medicinal properties (Rocha et al., 2001; Lindholm et al., 2002; Ruskin et al., 2002). Contemporary studies indicate the efficacy of many edible herbs, spices, fruits, and vegetables in decreasing the cancer incidence, due to the content of natural compounds present in them (Aruna and Sivarama krishnan, 1990; Unni and Kuttan, 1990; Dragsted et al., 1993).

SIGNIFICANCE OF SAFFRON (CROCUS *SATIVUS L.*) SPICE

C. sativus L. (*Iiridaceae*), generally called saffron, is the most expensive species of the world and is composed of orange-red color pungent stigmas; they are used in a dried form for flavoring and coloring foods as dye (Bakshi et al., 2007). Saffron is a perennial herb grown in Algeria, Azerbaijan, Australia, China, Egypt, France, Greece, Iran, India, Israel, Italy, Mexico, Morocco, New Zealand, Spain, Switzerland, Turkey, and United Arab Emirates. Folk's herbal medicines have included saffron as a remedy for several ailments because of its pain-relieving and sedative properties (Basker et al., 1983; Locock, 1995; Robinson, 1995) (Fig. 19.1). Owing to high demand, saffron is produced *in vitro*, and faster regeneration protocols have been developed for mass propagation (Bakshi et al., 2008). Saffron's biochemical characteristics have generated the interest of researchers during the last few years (Abdullaev et al., 1993, 2002; Souret and Weathers, 1999). Hartwell (1982) mentioned that in ancient era, saffron was made use of as an anticancer remedy as well as for preparations containing saffron extracts against different kinds of tumors and cancers. The stomach, spleen, liver, kidney, and uterus tumors have been treated with pharmaceutical preparations of saffron. In the early 1990s, some authors proved that natural saffron extracts presented antitumor, anticarcinogenic, antimutagenic effects, and cytotoxic properties (Nair et.al., 1995).

PHYTOCHEMISTRY OF SAFFRON *(C. SATIVUS L.)*

The approximate chemical assay of commonly available saffron (*C. sativus* L.,) had been done by several authors (Basker and Negbi, 1985; Skrubis, 1990; International Standards Organization, 1980a; Melchior and Kastner, 1974; Sampathuet al. 1984; Triebold andAurand, 1963; Stecher, 1968; Nicholls, 1945; Sastry et al., 1955; Indian Standard, 1969). The main purpose of *C. sativus* analysis is for the estimation of retrievable color intensity on macroscale or microscale amounts. The guarantee of correct botanical identification and mixing of low-quality materials such as floral waste were major difficulties faced for chemical analysis of saffron. It is practically unavoidable in supply to find the parts of the yellow-to-uncolored stigma, anthers, and some petals or even

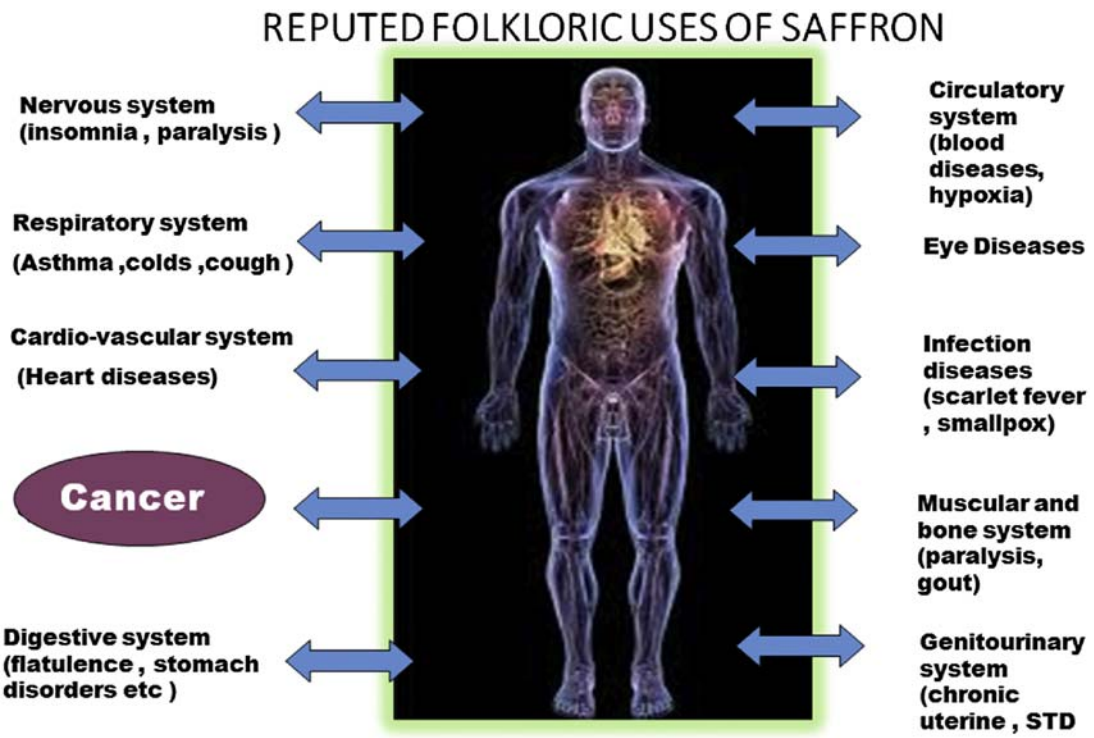

FIG. 19.1 Folkloric uses of saffron (Bakshi et al., 2008).

leaves (International Standard organization 1980a, 1980b; Hanson, 1973; Basker and Negbi, 1985).

Zechmeister (1962) reported that saffron is red-orange fundamentally because of a water-soluble carotenoid, a-crocin, a diester made from the disaccharide gentiobiose and dicarboxylic corrosive crocetin. The substance bond skeleton of alpha-crocin is made of shorter carbon chains of crocetin, which has nine conjugated twofold bonds; alpha crocin is additionally a glycoside, a concoction with a sugar displayed at the two finishes of carotenoid atom which makes it water solvent. Furthermore, water-soluble and water-insoluble carotenoid structures are available with a minor dimensional variation as detailed by different examiners (Pander and Witter 1975; Dhingra et al., 1975).

Complete constituent analyses have indicated that saffron contains approximately 10% moisture, 12% protein, and 5% each of minerals, fat, and crude fiber, and the rest is sugars, starch, dextrins, pectin, pentosans, and gums, including reducing sugars (% w/w).

Saffron at a trace level also contains vitamins such as riboflavin and thiamine (Rios et al., 1996). Biochemical research has been accomplished for portrayal of many biochemically dynamic medications found in saffron. The significant mixes in saffron found with bioactivity are crocetin (a characteristic carotenoid dicarboxylic corrosive forerunner of crocin), crocin (monoglycosyl or diglycosyl polyene esters), picrocrocin (monoterpene glycoside antecedent of safranal and result of zeaxanthin debasement), and safranal (Fig. 19.2), all these ingredients have the capacity to add to the shade, taste, and smell to enhance the quality (Rios et al., 1996).

There is a huge effect of atmosphere and genotype on compositional constituents of saffron, number of blooms, and disgrace yield, which were significantly changed by condition of the plant. The constituents of crocetin esters, namely (1) transcrocetin di-(b-Dgentibiosyl)ester, (2) transcrocetin (b-D-gentibiosyl) ester, (3) transcrocetin (b-D-glucosyl) (b-D-gentibiosyl) ester, (4) picrocrocin, and (5) trans-crocetin (b-D-glucosyl) ester were assessed by the spectrophotometric ISO standard technique, which positioned the examples into three subjectively diminishing classes (I–III); arrangement was assessed principally through the use of HPLC outfitted with a bright noticeable diode exhibit locator and electro-shower mass spectrometer identifiers (HPLC–UV–vis-DAD–ESI-MS), which made it conceivable to assess the metabolic qualities of disgrace

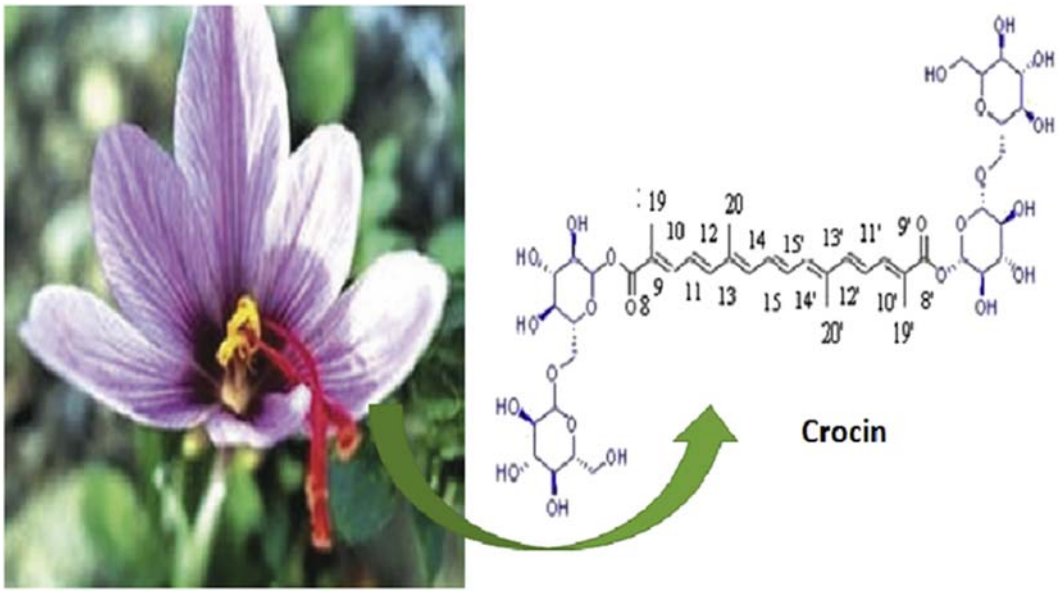

FIG. 19.2 Chemical structure of Crocin from saffron (Bakshi et al., 2008).

tests as far as picrocrocin and crocetin esters content. The mix of biochemical examination information with the natural conditions and genotype demonstrated that crocetin esters 1 and 2 make up the real parts of all-out crocetin ester sum, which likewise appears with a high positive connection (0.971 and 0.833, separately). In addition, the concentration of crocetin esters 2 (0.794) and 3 (0.818) and absolute crocetin esters (0.678) are closely related to the concentration of picrocrocin. In long term, a Pearson connection was performed so as to assess any conceivable connection between yield attributes (bloom number, complete yield, and unitary shame weight) and the subjective parameters of saffron (Siracusa et al., 2010).

The complete phenolics content in *C. sativus L.* corms in the torpid state and dynamic state was evaluated by the Folin-Ciocalteu strategy. The trial was performed on gas chromatography-mass spectrometry (GC-MS) after silylation by N-methyl-N-trimethylsilyl trifluroacetamide + %1 trimethyl iodosilane. A few synthetics were found, and 11 mixes were assessed. The most elevated phenolics content in dynamic corms was watched for genetic corrosive (5.693 ± 0.057 μg/g) and the least for gallic corrosive (0.416 ± 0.006 μg/g). These two phenolic mixes are the most noteworthy (0.929 ± 0.015 μg/g) and least (0.017 ± 0.001 μg/g) phenolics in torpid corms, individually (Esmaeiliet .al 2011). The outcomes from quantization and GC-MS investigation demonstrated a high centralization of phenolic mixes in dynamic corms than the idle state. What's more, the extreme purifying exercises of saffron corms were inspected by 1,1-diphenyl-2-pycrylhydrazyl test, and EC (50) values were resolved around 2055 and 8274 ppm for dynamic and torpid corms separately (Esmaeiliet.al 2011).

Carotenoids as Anti-Oxidative Damage Modifier

All carotenoids are oxidized by opening of C=C bonds to get oxygen molecules and, in this way, lessening the trademark shading. This procedure is improved by light. The conjugative sort security gives moderate assurance from oxidation; however, the oxidation response on these carotenoids shields the living cells from serious oxidation harm.

Mathews et al., (1982) reported the effect of gardenia crocetin on experimental skin tumors in nude mice and encountered a minor inhibitory activity on the progress of skin tumors induced by the application of croton oil and 9, 10-dimethyl-1, 2-benzanthracene. In rats, Gardenia crocin triggered major inhibitory activity against hepatocarcinogenic chemicals such as aflatoxin B1 and dimethyl nitrosamine as well as mildly reducing chronic hepatic damage in rats. This work was in agreement with that of Lin and Wang, 1986.

Tseng et al. (1995) reported that carotenoid plays essential functions in plant tissues protecting against oxidative damage. Consistent with this function in plants, gardenia crocetin decreased lipid peroxidation induced by reactive oxygen species in rat primary hepatocytes. A similar work was also conducted on Gardenia

crocin, and the water-soluble form also shows antioxidant properties at concentrations up to 40 ppm. At 20 ppm, the antioxidant activity of crocin is comparable to that of butylated hydroxyanisole (BHA).

Pham et al. (2001) reported that extracts from saffron and other carotenoid-containing spices showed significant hydrogen peroxide scavenging activity as measured by using peroxidase-based assay systems.

Martı′nez et al. (2001) revealed that carotenoids are soluble in lipids and might go about as a layer of connected free-radical controllers; the cancer prevention agent properties of these mixes could counteract DNA harm prompted by free radicals and free extreme chain responses.

Maggi et al. (2009) detailed that the drying is critical for saving the state of saffron, as it is required for discharging of safranal from picrocrocin by means of enzymatic procedure, the activity of releasing D-glucose and safranal, the unstable oil in saffron. There are six fundamental natural synthetic compounds found in saffron, and all are unstable; these include safranal, isophorone 2, 2, 6trimethyl-1, 4-cyclohexanedione, 4-ketoisophorone, 2-hydroxy-4, 4, 6-trimethyl-2, 5-cyclohexadien-1-one, just as 2, 6, 6-trimethyl-1,4-cyclohexadiene-1-carboxaldehyde.

PHARMACOLOGICAL AND BIOLOGICAL ACTIVITIES OF SAFFRON (*C. SATIVUS L.*)

From old occasions saffron reaped from dried, dull red marks of shame of *C. sativus L.* harvested in different occasions and their blossoms used as a medication to treat different human wellbeing conditions including hack, tooting, stomach issue, colic, a sleeping disorder, perpetual uterine hemorrhages, amenorrhea, dysmenorrheal, gynecological scatters (counting guideline of monthly cycle, reducing awkward period or absence of feminine cycle), red fever, smallpox, colds, asthma, and cardiovascular issue. Saffron (*C. sativus*) is a bulbous perpetual of the iris family (Iridaceae) cherished for its brilliant shaded, impactful marks of disgrace, which are dried and used to flavor and shade sustenances. Saffron is a zest known distinctly in development and mainly developed in Spain and Iran; in addition, they are grown on a lower scale in Greece, Turkey, India, Azerbaijan, France, Italy, India, China, Morocco, Turkey, Israel, Egypt, United Arab Emirates, Mexico, Switzerland, Algeria, Australia, and New Zealand (Abdullaev, 1993, 2002; Bakshi et al., 2007, 2008).

Gainer et al. (1976) reported that gardenia crocetin postponed the beginning and diminished the quantity of skin papillomas and Rous sarcoma tumors. The effect of gardenia crocetin on experimental skin tumors in nude mice showed a small inhibitory effect on the development of skin tumors induced by the application of 9, 10-dimethyl-1, 2-benzanthracene and croton oil (Mathews et al., 1982). In rats, gardenia crocins revealed a great protective effect against hepatocarcinogenic compounds such as aflatoxin B1 and dimethylnitrosamine, partially reducing chronic hepatic damage (Lin and Wang, 1986).

The orally controlling saffron ethanolic concentrates upgraded the life expectancy of Swiss pale-skinned person mice intraperitoneally joined with sarcoma-180 (S-180) cells, Ehrlich ascites carcinoma (EAC) or Dalton's lymphoma ascites (DLA) tumors. At this point, the creators did not distinguish the precise kind of the dynamic compound from saffron; however, they reported that this atom demonstrated the nearness of glycosidic security (Nair et al., 1991). Encapsulation of saffron can be done by liposome to efficiently increase its antitumor activity against S-180 and EAC solid tumors and potentiating it sufficiently to inhibit the growth of the tumors. Also, saffron stimulated nonspecific proliferation of lymphocytes in vitro because of the existence of the T-cell mitogen phytohemagglutinin. The antitumor activity might be immunologically mediated (Nair et al., 1992).

Abdullaev and Frenkel (1992) detailed for the first time that saffron reduce restrained development of harmful cells in vivo and in vitro. During the most recent decade, various examinations in a creature model framework exhibited the antitumor impact of saffron and its constituents on various dangerous cells. The carotenoid plays fundamental roles in plant tissues ensuring protection against oxidative harm. Reliably, with this capacity in plants, gardenia crocetin diminished lipid peroxidation actuated by receptive oxygen species in rodent essential hepatocytes (Tseng et al., 1995). The inhibitory action on the in vitro development of HeLa cells delivered by saffron extricates (ID50 ¼ 2.3 mg/mL) was mostly due to crocin (ID50 of 3 mM), although picrocrocin and safranal, with an ID50 of and 0.8 mM, individually, assumed a minor job in the cytotoxicity of saffron removes. These outcomes proposed that sugars may assume a job in saffron's cytotoxic impact as crocetin (the deglycosylated carotenoid) did not cause cell development restraint even at high dosages (Escribano et al., 1996). The treatment of creatures with cysteine (20 mg/kg body weight) alongside saffron extracts (50 mg/kg body wt) considerably decreased the dangerous harm done by cisplatin, similar to changes in chemical movement and nephrotoxicity (Daly, 1998).

Verma and Bordia (1998) announced that 50 milligrams of saffron in 100 mL of milk was given two times per day to human subjects, as revealed in an Indian investigation in 1998. The noteworthy reduction in lipoprotein oxidation powerlessness in patients with coronary artery disease (CAD) demonstrates the capability of saffron as a cell reinforcement.

It was demonstrated that crocin analogs secluded from saffron essentially expanded the blood stream in the retina and choroids just as encouraged retinal capacity recuperation. It was proposed that crocin analogs could be used to treat ischemic retinopathy as well as age-related macular degeneration (Xuan et al., 1999; Escribano et al., 1999a,b) detailed that the initiation of macrophages by the bioactive part separated from saffron corms at noncytotoxic focuses, estimated by the arrival of nitric oxide (NO). Treatment with 50 mg/mL multiplied the arrival of nitrate and nitrite by these cells. Higher fixations (up to 500 mg/mL) brought about a diminished NO creation in parallel with a checked fall in cell practicality. On the other hand, Garcı′a-Olmo et al. (1999) reported the effects of long-term treatment with saffron crocin (the glyosidic form of crocetin) on tumor growth and lifespan of rats bearing syngeneic colorectal tumors, induced by rat adenocarcinoma DHD/K12-PROb cells injected subcutaneously. Crocin treatment of those animals increased significantly their life span and reduced tumor-enlarging rate, faster in female mice. The selective action of crocin in female rats as compared with male rats suggests that the effects of crocin in animals might be partially dependent on hormonal factors.

An investigation on saffron, ginsenoside, and cannabinoid subordinates to decide potential film-related antitumor impacts of these substances. Saffron subordinates were ineffectual on the inversion of multidrug opposition of lymphoma cells (the inversion of multidrug obstruction is the after effect of the restraint of the efflux siphon work in the tumor cells). Crocetin esters were less intense than crocin itself in the restraint of early antigen articulation. In any case, diglucosylcrocetin and crocin averted early tumor antigen articulation of adenovirus-tainted cells, triglucosylcrocetin being less compelling. Crocin did not demonstrate any antiviral impacts on tainted Vero cells (Molnar et al., 2000). Gardenia crocin, the water-solvent structure, has likewise appeared at fixations up to 40 ppm. At 20 ppm, the cancer-prevention agent movement of crocin is tantamount to that of BHA. Concentrates from saffron and other carotenoid-containing flavors demonstrated huge hydrogen peroxide rummaging movement as estimated by using peroxidase-based test frameworks (Pham et al., 2001).

Premkumar et al. (2001) reported that the impacts of watery concentrates of saffron (created principally via carotenoids) in Swiss pale skinned person mice and recommended that pretreatment with saffron can essentially repress the dangerous impact on genetic materials of cells by cisplatin, cyclophosphamide, mitomycin, and urethane. Saffron extricate crocetin likewise diminishes bladder poisonous quality of the anticancer specialist cyclophosphamide without influencing its antitumor property (Nair et al., 1993). The most lipid-dissolvable carotenoids go about as layer-related free-radical foragers, and the cancer prevention agent properties of these mixes could avoid DNA harm initiated by free radicals and free extreme chain responses (Martı′nez et al., 2001)

The crocin detached from saffron shows antiapoptotic activity in PC-12 cells treated with daunorubicin. These discoveries propose that crocin hinders neuronal demise initiated by both inward and an outer apoptotic upgrade in exceedingly separated cells (neurons). This particular conduct proposes significant helpful ramifications, identified with the way that customized cell demise is diminished in malignancy and expanded in neurodegenerative illness (Soeda et al., 2001). Ozaki et al. (2002) announced no mutagenic action due to crocetin, while genipin, shaped by geniposide hydrolysis, caused DNA harm and initiated tetraploidy.

In Iranian conventional medication, the saffron had been used as an anticonvulsant cure. As of late, in investigations with mice using maximal electroshock seizure (MES) and pentylenetetrazole (PTZ) tests, it was exhibited that the fluid and ethanolic concentrates of saffron have anticonvulsant movement. It was recommended that saffron concentrates may be valuable in both nonattendance and tonic clonic seizures (Hosseinzadeh and Khosravan, 2002).

Since antiquated occasions, saffron collected from the dried, dim red marks of shame of *C. sativus L.* blossoms has been used as a medication to treat different human wellbeing conditions including hack, fart, stomach issue, colic, sleep deprivation, gynecological issue (counting guideline of feminine cycle, easing awkward period or absence of monthly cycle), red fever, little pox, colds, asthma, and cardiovascular issue (Abdullaev, 2003).

Fatehi et al. (2003) revealed the impacts of saffron petal on pulse in anesthetized rodents and on reactions of the segregated rodent vas deferens and guinea pig ileum incited by electrical field incitement (EFS). It was demonstrated that water and ethyl liquor concentrates of saffron decreased the circulatory strain in a portion subordinate way. EFS of the separated rodent vas deferens likewise were diminished by these saffron extracts.

The crocin family biosynthesis process was performed by using high pressure liquid chromatography (HPLC) to choose the glucosyltransferase activity and to make procedure for consolidating remedy from saffron cells. It was discovered that two glucosyltransferases are locked in with the advancement of crocetin glucosyl and gentiobiosyl-esters. GTase1 formed an ester bond between crocetin carboxyl social events and glucose moieties, while GTase2 catalyzed the course of action of glucosidic bonds with glucosyl ester packs at the two terminations of the molecule. Synthetic compounds can catalyze the improvement of crocetin glucosides in vitro. GTase1 activity is higher during introductory 4 days of crocin glucosides biosynthesis yet decreases in the following 4 days. The content of crocin increases in C. sativus cell cultures for the first six days and declined in subsequent experimental days (Yang et al., 2005). The flawlessness standards of crocin were surveyed in Indian saffron by clear, fast, and a preservationist crocin test system, and it was assumed that Indian saffron is rich in crocin, and excellence of blends exhibited relative results that stood out from sigma crocin (Chatterjee et al., 2005). The vital foe of secretory and antiulcer activities incited by the liquid suspension of saffron were evaluated against pylorus ligation (shay rodents), indomethacin, and distinctive narcotizing administrators in rodents. Histopathological assessment of rat stomach did not show any malicious ramifications for extreme and interminable toxic quality (Mofleh et al., 2006).

Saffron is promising alternative approach to achieve cure; the technique for saffron's anticancer activity is generally unknown, and several experts have proposed the part of development of the medicine Saffron. Scientists reported that saffron may unequivocally attack DNA courses of action and change quality verbalization. Bathaie demonstrated that carotenoids (crocin, crocetin, and dimethylcrocetin) of saffron clearly bind to DNA minor scores and produce conformational changes of express DNA (Bathaie et al., 2007).

The little yield of saffron and related more noteworthy cost actuated determined workers tragically to pollute as far back as a couple of hundreds of years. In the fourteenth century, Nuremberg, Germany, was the point of convergence of the European saffron business with saffron created in Austria, Sicily, France, Crete, Greece, and Spain, encountering its dealers. In any case, an incredible piece of the saffron was sullied in a guile and dumbfounded way, tragically. The Safranschou Code was familiar and maintained all together with a guarantee of the validity of saffron, the code containing unequivocal saffron measures and disciplines for defilement. The coercion disciplines were not kidding in light of the fact that experts were endorsed by the code to keep or execute people found at risk of defiling saffron. Trading of saffron is very attractive due to its market price and its increasing demand is an extensive beguiling (Hagh-Nazari and Keifi, 2007).

In the twofold outwardly weakened randomized and counterfeit treatment controlled primer, 30 mg/day of saffron compartment supplementation (15 mg twice step by step: morning and night) was convincing in treating premenstrual cycle issue (PMS) in women developed 20−45 with standard menstrual cycles and PMS system experience for at any rate a half year (Agha-Hosseini et al., 2008). The anxiolytic properties of crocin were considered in animals, and it was seen that 50 mg/kg bt wt segment of crocin extended motor development when stood out from diazepam. It was also shown that lower measurements of crocin did not modify animals lead (Pitsikas et al., 2008).

C. sativus liquid concentrate's sexual enhancement activities were evaluated in male rodents in addition to its constituents safranal and crocin. Mounting repeat (MF), intromission repeat (IF), erection repeat (EF), mount inertness (ML), intromission torpidity (IL), and release idleness (EL) were the factors evaluated during the sexual lead consider. Crocin, at all doses, and the concentrate, especially at bits 160 and 320 mg/kg body wt., extended MF, IF, and EF rehearses and reduced EL, IL, and ML parameters. Safranal did not show a sexual enhancement property however the crocin major constituent of saffron derived from its aqueous extract demonstrated for sexual enhancement (Hossinzadeh et al., 2008).

The counter ulcer capability of saffron is observed in mice, which also affirms its customary use against gastric disorders. The study was intended to examine the viability of three unique medications (ethanol saffron extricate, business saffron remove, and crocin) and to exhibit that every one of the three segments showed antiulcer action, such as omeprazole, the proton siphon inhibitor being utilized to treat peptic ulcer. Saffron, crocin, and safranal showed cancer prevention agent properties that repressed ulcer arrangement by stifling indomethacin-caused gastric mucosa harm by raising glutathione levels and hampering lipid oxidation (Kianbakht and Mozaffari, 2009; Xu et al., 2009). Nabavizadeh et al. (2009) revealed that 100 mg/kg of fluid saffron separate caused elevated yields of gastric corrosive and pepsin in Wister rodents and demonstrated process improvement of saffron.

Mousavi et al. (2009) detailed that saffron concentrate of 200−2000 μg/mL inhibited portion subordinate multiplication of MCF-7 cells, IC50 = 400 ± 18.5 μg/mL

after 48 h. Similarly detailed were the entrancing, anxiolytic loco engine, and engine coordination movement of saffron, saffronal and crocin in mice using a pentorbital rest time test, an assessed maze test, an open field test, and a rotarod test (Hossinzadeh and Noraci, 2009).

The job of caspases and Bax protein in MCF-7 cells in saffron-actuated apoptosis is in the arrangement of cell culture for bosom malignancy in in vitro investigations. Saffron-delivered apoptosis can be avoided by master caspase inhibitors, proposing caspase-subordinate pathway was initiated by saffron in MCF-7 cells. Bax protein articulation was likewise expanded in saffron-treated cells. Along these lines, saffron has genius apoptotic impacts on a bosom malignancy inferred cell line and could be considered as a potential chemotherapeutic operator in bosom disease (Mousavi et al., 2009).

Shamsa et al. (2009) detailed the impact of *C. sativus* (saffron) contemplated on male erectile dysfunction (ED). Twenty male patients with ED were pursued for 10 days in which every morning they took a table containing 200 mg of saffron. Patients underwent the nighttime penile bloat (NPT) test and the worldwide record of erectile capacity poll (IIEF15) toward the beginning of the treatment and toward the end of the 10 days of trial. After the 10 days of taking saffron, there was a factually huge improvement in tip unbending nature and tip distension just as base inflexibility and base tumescence. ILEF-15 aggregates' centers were essentially higher in patients after saffron treatment (before treatment 22.1571.44; after treatment 39.2071.90, po0.001). Saffron demonstrated a constructive outcome on sexual capacity with an expanded number and span of erectile occasions found in patients with ED even simply subsequent to taking it for 10 days.

The free radical rummaging and lipid peroxidation avoidance of crocin from *C. sativus* is discussed. The preclinical examination exhibits that crocin is compelling in restraining free extreme development and furthermore to assault the free radicals (Bakshi et al., 2009). The toxicological impacts and in vitro cancer-prevention agent property of the ethanolic concentrates of *C. sativus* and Propolis were inspected. These concentrates did not cause any mortalities or indications of poisonous quality in mice when regulated orally at dosages of up to 5 g/kg b.wt. In the subendless investigation, the tried concentrates did not cause any critical change in liver and kidney elements of rodents, after oral administration for eight progressive weeks at dosages of 500 mg/kg b.wt. of each. Propolis indicated noteworthy in vitro cancer prevention agent action at concentrations of 40−100 mg/mL. Conversely, the ethanolic extract of *C. sativus* indicated frail cell reinforcement movement in convergences of 1−10 mg/mL while at 20−100 mg/mL concentration it failed to show any cancer-prevention agent action. Oral administration of C. sativus every day, propolis ethanolic separates alone or in blend, for eight progressive weeks to rodents was found to be safe and did not cause any poisonous changes in the liver and kidney. Cell reinforcement study demonstrated that propolis ethanolic concentrate was a more powerful cancer-prevention agent than *C. sativus* (Ramadan et al., 2010). In our examination to analyze the impact of crocin, the vital compound in saffron, against in vitro and in vivo xenograft counteractive action of Dalton's lymphoma, we uncovered huge increment in life expectancy of Dalton's lymphoma−bearing creatures with 95.6% reduction of strong tumor in crocin-treated creatures on the 31st day of tumor vaccination. This examination urged us to further proceed with our exploration on crocin (Bakshi et al., 2009).

To completely and distinctively comprehend, regardless of whether crocin or crocetin stifles, microglial enactment was considered. Crocin and crocetin were demonstrated to be successful in restraining LPS-initiated nitric oxide (NO) discharge from refined rodent cerebrum microglial cells. These mixes decreased the LPS-animated preparations of tumor rot factor-α, interleukin-1β, and intracellular responsive oxygen species. The mixes additionally successfully diminished LPS-evoked NF-κB enactment. What's more, crocin diminished NO discharge from microglia animated with interferon-γ and amyloid-β. In organotypic hippocampal cut societies, both crocin and crocetin hindered the impact of LPS on hippocampal cell passing. These outcomes recommend that crocin and crocetin give neuroprotection by reducing the creation of different neurotoxic atoms from initiated microglia (Nam et al., 2010).

Crocetin is a pharmacologically dynamic carotenoid compound of Gardenia jasminoides Ellis which is used as a customary home-grown prescription and regular colorant. The pilot analysis was intended to comprehend the impact of crocetin on rest. The clinical study involved a twofold, visually impaired, fake treatment controlled, hybrid preliminary of 21 sound grown-up men with a gentle rest objection. It included two mediation times of about 14 days each, isolated by a 2-week washout period. The target rest quality was estimated by using an actigraph and evaluated the emotional side effects utilizing St. Mary's Hospital Sleep Questionnaire. Actigraph information demonstrated that after administration of crocetin, the quantity of arousing scenes decreased in contrast with that of the fake treatment ($P = .025$). Emotional information from St. Mary's Hospital Sleep Questionnaire demonstrated that crocetin would, in general, improve the nature of rest

contrasted with rest before its admission. Furthermore, no reactions from crocetin admission were watched. The outcomes recommend that crocetin may add to improving the nature of sleep (Kuratsune et al., 2010; Kuratsune et al., 2010).

The protective effects of crocin against cisplatin-induced renal oxidative stress in rats were studied. Blood chemistry and biochemical and histopathological examination were done, and it was concluded that crocin significantly protects against cisplatin-induced renal toxicity (Naghizadeh et al., 2010). To study antidepressant properties of stigmas and corms of *C. sativus* L., the aqueous ethanol extract of *C. sativus* corms was fractionated on the basis of polarity. Among the different fractions, the petroleum ether fraction and dichloromethane fraction at doses of 150, 300, and 600 mg/kg showed significant antidepressant-like activities in dose-dependent manners, by means of behavioral models of depression (Yang et al., 2010). All these results suggest that the low polarity parts of *C. sativus* corms should be considered as a new plant material for curing depression, which merit further studies regarding antidepressive-like activities of chemical compounds isolated from the two fractions and mechanism of action (Yang et al., 2010).

The impacts of three convergences of macerated concentrate of saffron (*C. sativus L.*), dexamethasone, and saline on cell practicality and generation of cytokines, including interleukin (IL)-4, IL-10, and interferon-γ (IFN-γ), were assessed. In cells animated with PHA, various groupings of the concentrate essentially hindered cell feasibility of lymphocytes. High groupings of the concentrate (500 μg/mL) additionally restrained emission of IFN-γ in invigorated cells and IL-10 discharge in both animated and nonstimulated cells. The impacts of high and low convergences of the concentrate (500 and 50 μg/mL, individually) on IL-4 emission were lower than those of dexamethasone. The concentrate demonstrated a stimulatory impact on IFN-γ and IL-4 emission in no invigorated cells. The proportions of IFN-γ to IL-4 within the sight of all groupings of saffron on animated cells were essentially higher than those for the control gathering results showed that the concentrate of saffron has the potential to intervene provocative markers (Boskabadyet.al 2011).

Potential of Dietary Crocin the Marker Compound in Saffron (*C. sativus L.*) Against Different Malignancies

Previous studies have shown a variety of pharmacological effects of dietary crocin (Aung et al., 2007; Bakshi et al., 2009); however, the mechanism underlying antitumor activity of crocin remains unclear. Different hypotheses had been propounded to explain its anticarcinogenic and antitumor action. The crocin induced apoptosis in HeLa and K562 cells (Escribano et al., 1996), while other studies have indicated the role of free radicals chain reaction in its antitumor action (Premkumar et al., 2001). The induction of apoptosis by saffron in human cancer cell lines was also shown in our previous study (Bakshi et al., 2008). *In-vivo* experiments on athymic bare mice had reasoned that crocetin, a carotenoid compound got from saffron, could actuate apoptosis in pancreatic tumors in athymic naked mice (Dhar et al., 2009). In 2011, Sun et al., through their examinations, had inferred that the preventive impact of crocin was on DNA and RNA amalgamation yet not on protein union, and in any case, it is hypothesized that it could be the conceivable component of crocin-actuated apoptosis (Sun et al., 2011).

Various speculations for the methods against cancer-causing and antitumor activities of saffron and its constituents have been recommended. One of the instruments for the antitumor or cancer-causing activity of saffron and its parts is the preventive impact on cell DNA and RNA union and not on protein combination (Sun et al., 2011; Nair et.al., 1995; Abdullaev et al., 1995/1996). The second component for the antitumor activity of saffron and its constituents is the preventive impact on free extreme chain responses, as carotenoids are lipid soluble and might go about as film bound high-effectiveness free extreme destroyer, which is associated with their cell reinforcement properties (Molnar et al., 2000; Verma et al., 1998; Tseng et al., 1995). The third proposed system by which the saffron concentrate demonstrates its antitumor activity is the metabolic change of carotenoids to retinoids (Tarantilis et al.,1994; Dufresne et al., 1997), yet, as of late, it was accounted for that transformation of carotenoids to nutrient. Anti cancer activity of *C. sativus* derived active principles is unquestionable (Smith, 1998). The fourth estimated instrument is that the cytotoxic impact of saffron is associated with cooperation of carotenoids with topoisomerase II, a chemical related with cell DNA-protein communication (Smith, 1998; Molnar et al., 2000). Notwithstanding, these examinations give signs to the examinations of the biochemical and subatomic instruments of antitumor impacts of crocin. With this scenery, in this venture, I am proposing to explore the activity of dietary crocin in different human disease cell lines and concentrate the adjustment in the outflow of apoptosis qualities in connection to its cytotoxic dimensions.

Past specialists have strived to clarify against disease and chemopreventive impact of crocin through their

investigations; however, no agreement can be reached upon its method of activity. An ongoing report had demonstrated that crocin hinders telomerase action by downdirecting interpretation of hTERT quality in HepG2 cell line (Noureini and Wink, 2012). The abatement of telomerase movement in HepG2 cell treated with crocin concurs with an ongoing report demonstrating that crocin displays hostile to proliferative impacts in human colorectal malignant growth cell lines while not influencing typical cells (Aung et al., 2007). The perception of decrease in telomerase action additionally acclimates with aftereffects of another report that presumed that crocin subordinates were increasingly dynamic in tumor cell settlement arrangement in an in vitro examine ponder than different carotenoids (Bakshi et al., 2010; Sun et al., 2011), in this manner diminishing clearness on its method of action. In option, crocin and crocetin were appeared to restrain bosom malignant growth cell expansion (Chryssanthi et al., 2007). The in vitro and in vivo investigations have effectively affirmed a fixation and time subordinate development restraint by crocin in xenograft mouse models (Bakshi et al., 2009). Another examination had demonstrated the improvement of cytotoxic and apoptogenic properties of crocin in malignant growth cell lines, HeLa and MCF-7, utilizing its nanoliposomal structure, which make it increasingly productive at impressively lower IC50 values (Mousavi et al., 2011). Apoptosis enlistment by saffron and its constituents has appeared in few investigations without clarifying the component of activity. Saffron concentrate prompted apoptosis in human malignancy cell line (Bakshi et al., 2008). The crocetin, a carotenoid compound got from saffron, could actuate apoptosis in pancreatic cells just as athymic naked mice tumor (Dhar et al., 2009). The restraint of caspases could square saffron-initiated apoptosis in MCF-7 cells in this manner, demonstrating caspase-subordinate pathways were incited by saffron in MCF-7 cells and a few factors other than caspases, for example, apoptosis actuating factor (AIF) may not be especially included. Bax articulation was discovered expanded, proposing a mitochondrial pathway including apoptosis (Mousavi et al., 2009). However, the precise atomic mechanism(s) of crocin incited cell demise in disease is as yet not clear.

In later past, a portion of our work on dietary crocin has showed free radical searching and lipid peroxidation hindrance (Bakshi et al., 2009), apoptosis and cell cycle capture in pancreatic malignancy cell lines (Bakshi et al., 2010), cytotoxic and apoptogenic impact of "CS" on various Human disease cell lines (Bakshi et al., 2008), in vitro and in vivo xenograft restraint of Daltons lymphoma (Bakshi et al., 2009), breast disease cell (MCF-7) passing by enacting caspase flagging (Bakshi et al., 2016a), and low centralization of crocin can execute the cervical malignant growth (Hep-2) cell by saving ordinary vero cells (Bakshi et al., 2016b). Moreover pervious examination demonstrated that saffron concentrate is protected in in vivo model (Bakshi et al., 2016a) and that dietary crocin hinders dangerous melanoma in in vivo model (Bakshi et al., 2017a) and turns around melanoma metastasis (Bakshi et al., 2017b). This demonstrated crocin can possibly convert into centers. However, progressively future unthinking exploration is expected to completely comprehend job of crocin in malignant growth counteractive action.

HINDERING IMPACTS OF SAFFRON

The absence of saffron wellbeing data has prompted research focusing on this significant issue. The few investigations that have been directed have delivered conflicting results. In few cases, infusions of 1.2−2 g/per normal saffron body weight may cause sickness, spewing, loose bowels, and dying, while in different cases, no unfriendly impacts have been related with ingestion of 4 g of saffron for every day for a few days, incorporating into pregnant ladies. Anyway it is not evident whether these German investigations utilized *C. sativus* or if the investigations were completed utilizing knoll saffron (Colchicum autumnale), which is rich in Germany (Schmidt et al., 2007). As per another examination, portions of in excess 10 g of saffron may initiate premature birth with announced symptoms including diminished hunger, drowsiness, queasiness, regurgitating, uterine dying, hematuria, the gastrointestinal mucosal dying, vertigo, and dazedness (Schmidt et al., 2007). Safran concentrate causes unfavorably susceptible responses in extremely uncommon cases (Lucas et al., 2001). Saffron has a high LD50 = 20 g/kg that clarifies why toxicology specialists think of it as safe for human utilization right now (Bisset and Wichtl, 1994). The real measure of saffron utilized in nourishment regularly is much lower than the portion that causes any of the announced symptoms. The portion required in this survey for positive medical advantages is reliable within the measure of saffron utilized in various kitchens. In vivo examinations in creatures demonstrate an extremely low or even nonexistent danger of both saffron and its concentrates in contrast to many human investigations (Karimi et al., 2001; Nair et al., 1991, 1995). It ought to be noticed that the utilization of in vitro or in vivo creature studies has demonstrated huge number of the beneficial outcomes of saffron;

however, it stays hazy whether these constructive outcomes are indistinguishable in people. Further clinical research is justified so as to explain the potential advantages or destructive impacts in people.

CONCLUSION

The overall population acknowledges the utilization of saffron for nourishment, shading, and seasoning all through the world and by numerous social groups. Scientists around the globe are anyway more pulled in to the capability of saffron for natural or pharmacological capacity, which is because of the huge number of phytochemicals found in saffron. In numerous in vitro and in vivo examinations, safranal, crocetin, crocins, and picrocrocin are considered among these phytochemicals to be the most restoratively bioactive and the most analyzed. These tests unmistakably demonstrate that saffron utilization is emphatically related with lower sickness hazard, including metabolic issue (gastric turmoil), premenstrual disorder, despondency, a sleeping disorder and uneasiness, cardiovascular illness, and numerous malignancies. Notwithstanding, the best perceptions were seen in creature models, bringing up numerous issues: How do these potential advantages convert into human models? Is there any distinction between saffron creature resistance and human resilience? How sheltered is man's saffron. It must be viewed as that different impacts could be conceivable because of saffron rough concentrates (which contain all phytochemicals) and their bioactive mixes (filtered phytochemicals). Further preliminaries are required so as to understand the refinement in wellbeing points of interest attributable to unrefined concentrates and cleaned types. Regarding medicinal use, further large-scale epidemiological examinations, clinical investigations, and research facility study are required to explain the procedures and effects of saffron on human wellbeing.

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Internet of Things (IoT) Applications – An Inclusive Review

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***Abstract*---**With the advances in the Internet of Things (IoT), there exits ever-growing demand in different application domains which uses multiple heterogeneous devices. IoT is one of the most productive and powerful wireless communication models. The common concept is things that are identifiable, readable, controllable, addressable, and locatable through the Internet. The IoT combines embedded devices and sensors to share information through the Internet. In the IoT environment, all objects of everyday life can be connected with the Internet for computing and communication purposes. IoT increases the viewpoint of the Internet and creates it more appropriate for various applications. For the reason that, IoT has to turn into more favorable in various application domains such as health monitoring, assisted living monitoring, smart home automation systems, and Industrial monitoring, etc. This paper deals with most frequently used IoT applications and their significance usage. In addition to, technical challenges, technologies used in each application, protocols and sensors used for each application are also highlighted.

***Keywords*---**IoT, Applications, Challenges, Sensors used in IoT, Technologies and Protocols.

I. INTRODUCTION

THE Internet of Things (IoT)is a significant concept in recent years as a term to explain the association of non-traditional devices, such as factory machinery, medical equipment or domestic appliances, to the internet. Over the past few decades, the use of microprocessor-based controllers in applications from toasters to airliners has become ubiquitous. IoT can look at the next step in the development of these controllers by connecting them to the internet [1].

Home automation or Smart Homes can be explained as adding technology within the home environment to offer convenience, comfort, security and energy efficiency to its residents [2]. With the development of the Internet of Things, the research and implementation of home automation are getting more popular [3].

Medical care and health care are some of the most significant application areas in the IoT. The IoT can provide many medical applications like remote health monitoring, fitness programs, chronic diseases, and elderly care [4].

The Industrial Internet of Things (Industrial IoT) is made up of a multitude of devices connected by communications software. The resulting systems, and even the individual devices that comprise it, can monitor, collect, exchange, analyze, and instantly act on information to intelligently change their behavior or their environment – all without human intervention" [5].

The Industrial Internet of Things (IIoT), is a concept that incorporates sensor networks and control systems, which has been operating in several industries to enhance productivity and safety [6].

The rest of the paper is structured as follows. In Section II, describes briefly about Smart home automation. Section III, describes the Health care application, Section IV focuses on the Industrial IoT, the conclusion is drawn in section V.

II. SMART HOME AUTOMATION

With the growth of the Internet of Things (IoT), smart home appliances like smart TVs, smart refrigerators, smart washers, smart cooling and heating devices have been popularly used and such smart home appliances are linked together to the internet and make people's life easier. The smart home automation system incorporates the control system, internal and external factors of a house, such as lighting, temperature, doors, and windows. The smart home service can set lighting, control temperature based on personal availability and change music, TV programs differently depends upon the user's experience and preference [7].

The smart air conditioning system can anticipate the house occupancy by tracking location and achieve the desired comfort level when the house is occupied and saves energy when it is not. For further comfort, the Smart Home can facilitate independent living for the aging. It can help with daily tasks such as cleaning, cooking, shopping, and laundry. Home health monitoring can produce a signal to caregivers who respond before expensive and disruptive hospitalization is needed [1].

In the majority of IoT-based home automation systems, placed actuators and sensors inside the home environment to control and monitor its operations. Then these devices are connected to the local server through the wireless medium for data collection and analysis [8]. Through the smart-phone, people can control and monitor their homes from anywhere and anytime. However smart home appliances for the smart home are vulnerable to attacks and leads to security violations. So we are in need of secure based smart home automation because sensor information contains personal information (hobbies, habits, medical service, etc.), and financial information too [7].

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OP - 1

IN VITRO ANTICANCER PROFILE OF TRAGIA PLUKENETII RADCL. - SM LEAVES AGAINST LUNG CANCER AND CHRONIC MYELOID LEUKEMIA CELL LINES

Manoharan Sowmya Priya [1], Sangilimuthu Alagar Yadav*, Reshma.P[2]
Samba S. Nelsan[3]
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ABSTRACT

The most important aspects of health treatment are medicinal plants. Indian medicinal plants offer common knowledge for natural immunity and pathological diseases to restore. Thus, *Tragia plukenetii* has a wide range of medicinal properties such as antitumor, antimutagenic, antigenotoxic activities, antinociceptive activity, antihyperglycemic properties, antioxidant activities, analgesic, and anti–inflammatory activity. In the present study, the phytoconstituents of *T. plukentii* leaves showed higher antioxidant levels as evident from *in-vitro* assays. The bioactive compounds that responsible for antioxidant activity were found to be compound 1 (dec–9–en–1–ol) & compound 2 (dodeca–1, 11–dien–3–one) as analyzed though column chromatography, FTIR, NMR and GC–MS. In DPPH radical scavenging activity, the compound 1 & 2 showed 80% and 60% of inhibition, respectively. Further, C1 and C2 were subjected to MTT assay and showed the IC50 as 76.15 and 79.96, in K(562) respectively. The inhibition of A(549) cell line by C1 and C2 was determined as 87% and 91% at 85 µl concentration, respectively. Besides flow cytometry analysis proved that C2 is a potent cytotoxic agent against A(549) having 82% of cell inhibition. Hence, it is concluded that *Tragia plukenetii* is likely to be a key path to a novel medicament for fewer side effects on lung cancer.

KEYWORDS: *Tragia plukenetii*, Anticancer, Antioxidant, GC–MS, FT–IR, NMR, MTT, Flow cytometry and cell viability.

OP - 15

METABOLIC PROFILING AND BIOLOGICAL ACTIVITIES OF *ARTABOTRYS HEXAPETALUS* LEAVES

Balamurugan Pandiyan[1] and Sangilimuthu Alagar Yadav[1*]

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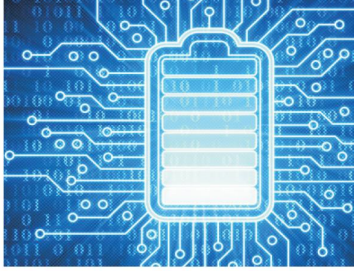
ABSTRACT

Artabotrys hexapetalus, an endemic shrub in India producing fragrant flowers belongs to Annonaceae family and is mainly used traditionally for the treatment of cholera and scrofula. Present study reveals antimicrobial, antioxidant and anticancer commotion of dissimilar solvent extract of *Artabotrys hexapetalus*. to reveal the major secondary metabolites and antioxidant potentials by using *in vitro* antioxidant models in different solvent extracts and to isolate the active phytoconstituents from selected extract and cytotoxicity beside breast cancer cell line (MCF–7) for isolated fractions from highly active extract of *A.hexapetalus* leaves. All successive extracts of methanol, EtOH, ethyl ethanoate, trichloromethane and pet-ether were obtained by Soxhlet method and subjected to phytochemical screening. Total phenolic and flavanoid contents were estimated and DPPH radical scavenging assay, Ferrous reducing power, Hydrogen peroxide radical scavenging activity and Fe^{2+} chelating activity were also performed to find out the *in vitro* antioxidant activity of the extracts. Antibacterial activity and anticancer activity were determined by various methods.Here, we conclude that the methanol extract of *A.hexapetalus* leaves and their fractions possess highly active properties against various free radicals, human pathogens and cancer cell line (MCF–7). This is the key guide to make a new biological agent from *A.hexapetalus* leaves.

KEYWORDS: *Artabotrys hexapetalus,* cytotoxicity, phytoconstituents, MCF–7, Antioxidant activity, phenolic and flavonoid content.

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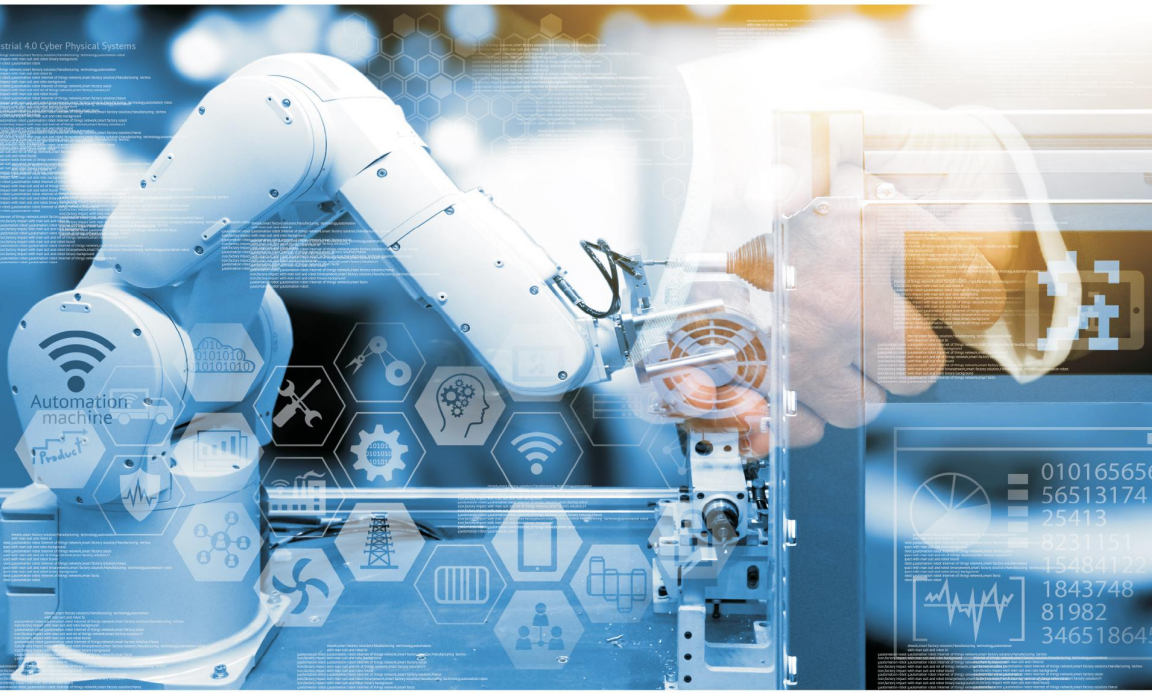

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Contents

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Reactive-Power Control in Electrical Power Transmission Systems

Dr. A. Amudha[1], Dr. G. Emayavaramban[2],
Dr. Ir.Viyathukattuva[3], Dr. M. Siva Ramkumar[4]

Reactive Power

In this chapter, an understanding of reactive power associated with power- transmission networks is developed. To make transmission networks operate within desired voltage limits, methods of making up or taking away reactive- power—hereafter called *reactive-power control*—are discussed. Before pro- ceeding further, however, a thorough understanding of the reactive power in ac systems is necessary.

Upon energization, the ac networks and the devices connected to them create associated time-varying electrical fields related to the applied voltage, as well as magnetic fields dependent on the current flow. As they build up, these fields store energy that is released when they collapse. Apart from the energy dissipa- tion in resistive components, all energy-coupling devices, including transform- ers and energy-conversion devices (e.g., motors and generators), operate based on their capacity to store and release energy.For the ac circuit shown in Fig. 2.1(a), instantaneous power from the voltage source to the load $Z\angle\mathbf{f}$, in terms of the instantaneous voltage v and current i, is given as

$$p = vi \qquad \ldots 1.1$$

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In the steady state, where $v = V_{max}\cos(\omega t)$ and $i = I_{max}\cos(\omega t - \phi)$:

$$p = \frac{V_{max}I_{max}}{2}[\cos\phi + \cos(2\omega t - \phi)]$$
$$= VI\cos\phi(1 + \cos 2\omega t) + VI\sin\phi\sin 2\omega t$$

Where V and I are the respective root mean square (rms) values of v and i.

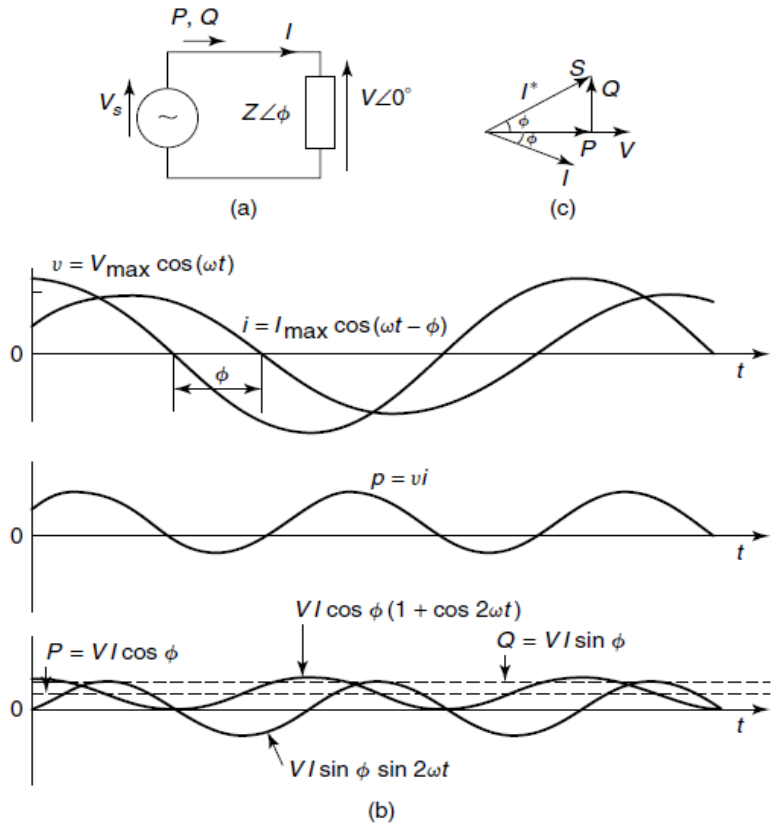


Fig. 1: The Electrical Parameters In An Ac Network.

Above Equations are pictorially represented in Fig. 1.1(b). Equation (2.2) comprises two double-frequency (2q) components. The first term has an average value as well as a peak magnitude of $VI\cos$ **f**. This average value is the active power, *P*, flowing from the source to the load. The second term has a zero average value, but its peak value is

$VI \sin \mathbf{f}$. Written in phasor domain, the complex power in the network in Fig. 2.1(a) is given by

$$S = \overline{V} \cdot \overline{I}^*$$
$$= P + jQ = VI \cos \phi + jVI \sin \phi$$

Where P is called the active power, which is measured in watts (W), and Q is called the reactive power, which is measured in volt–ampere reactive (var). Comparing Eqs. (2.3) and (2.2), the peak value of the second component of instantaneous power in Eq. (2.2) is identified as the reactive power.

The reactive power is essential for creating the needed coupling fields for energy devices. It constitutes voltage and current loading of circuits but does not result in an average (active) power consumption and is, in fact, an important component in all ac power networks. In high-power networks, active and reactive powers are measured in megawatts (MW) and MVAR, respectively. Figure 2.1(c) shows a commonly used power triangle.

Electromagnetic devices store energy in their magnetic fields. These devices draw lagging currents, thereby resulting in positive values of Q; therefore, they are frequently referred to as the absorbers of reactive power. Electrostatic devices, on the other hand, store electric energy in fields. These devices draw leading currents and result in a negative value of Q; thus they are seen to be sup- pliers of reactive power. The convention for assigning signs to reactive power is different for sources and loads, for which reason readers are urged to use a consistent notation of voltage and current, to rely on the resulting sign of Q, and to not be confused by absorbers or suppliers of reactive power

Uncompensated Transmission Lines

To develop a good, qualitative understanding of the need for reactive-power control, let us consider a simple case of a lossless short-transmission line connecting a source V_S to a load $Z\angle\mathbf{f}$. (For simplicity, the line is represented only by its inductive reactance Xl .) Figure 2.2 shows such a network with its parameters, as well as a phasor diagram showing the relationship between voltages and currents. From Fig. 2.2(b), it is clear that between the sending- and the receiving-end voltages, a magnitude variation, as well as a phase difference, is created. The most significant part of the voltage drop in

the line reactance (DV_1 c$j\,I_x X_l$) is due to the reactive component of the load current, I_x. To keep the voltages in the network at nearly the rated value, two control actions seem possible:

1. Load compensation, and
2. System compensation.

Load Compensation

It is possible to compensate for the reactive current I_x of the load by adding a parallel capacitive load so that I_c c $-I_x$. Doing so causes the effective power factor of the combination to become unity. The absence of I_x *eliminates* the voltage drop DV_1, bringing V_r *closer* in magnitude to V_s; this condition is called *load compensation*. Actually, by charging extra forsupplying the reactive power, a power utility company makes it advantageous for customers to use load compensation on their premises. Loads compensated to the unity power factor reduce the line drop but do not eliminate it; they still experience a drop of DV_2 from $j\,I_r X_l$.

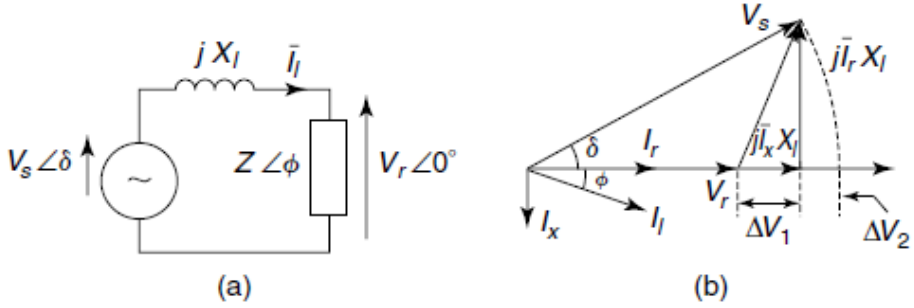


Fig. 2: A Short, Lossless Transmission Line Feeding a Load.

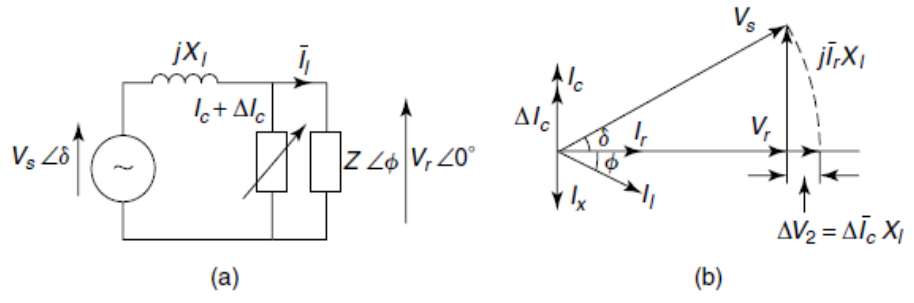


Fig. 3: The Reactive-Power Control For Voltage Regulations.

System Compensation

To regulate the receiving-end voltage at the rated value, a power utility may install a reactive-power compensator as shown in Fig. 2.3. This compensator draws a reactive current to overcome both components of the voltage drop DV_1 and DV_2 as a consequence of the load current I_l through the line reactance X_l. To compensate for DV_2, an additional capacitive current, DI_C, ov_er and above I_C that compensates for I_X, is drawn by the compensator. When $DI_C X_l$ c DV_2, the receiving-end voltage, V_r, equals the sending-end voltage, V_S. Such compensators are employed by power utilities to ensure the quality of supply to their customers.

Lossless Distributed Parameter Lines

Most power-transmission lines are characterized by distributed parameters: series resistance,r; series inductance, l; shunt conductance, g; and shunt capacitance, c—all per-unit (pu) length. These parameters all depend on the conductors' size, spacing, clearance above the ground, and frequency and temperature of operation. In addition, these parameters depend on the bundling arrangement of the line conductors and the nearness to other parallel lines.

The characteristic behaviour of a transmission line is dominated by its l and c parameters. Parameters r and g account for the transmission losses. The fundamental equations governing the propagation of energy along a line are the following wave equations:

$$\frac{d^2\overline{V}}{dx^2} = zy\overline{V}$$

$$\frac{d^2\overline{I}}{dx^2} = zy\overline{I}$$

where $zy = (r + j\omega l)(g + j\omega c)$.

For a lossless line, the general solutions are given as

$$\overline{V}(x) = \overline{V}_s \cos \beta x - jZ_0\overline{I}_s \sin \beta x$$

$$\overline{I}(x) = \overline{I}_s \cos \beta x - j \frac{\overline{V}_s}{Z_0} \sin \beta x$$

These equations are used to calculate voltage and current anywhere on line, at a distance x from the sending end, in terms of the sending-end voltage and current and the line parameters.

$Z_0 = \sqrt{\frac{l}{c}}\ \Omega$ = the surge impedance or characteristic impedance

$\beta = \omega\sqrt{lc}$ rad/km = the wave number

$\beta a = \omega\sqrt{lca}$ rad = the electrical length of an a-km line

where l is the line inductance in henries per kilometer (H/km), c is the line-shunt capacitance in farads per kilometer (F/km), and $1/\sqrt{lc}$ is the propagation velocity of electromagnetic effects on the transmission line. (It is less than the velocity of light.)

$$\bar{I}_s = \frac{\bar{V}_s \cos \beta a - \bar{V}_r}{jZ_0 \sin \beta a}$$

If $\bar{V}_s = V_s\angle 0^\circ$ and $\bar{V}_r = V_r\angle -\delta = V_r(\cos\delta - j\sin\delta)$, then

$$\bar{I}_s = \frac{V_r \sin\delta + j(V_r \cos\delta - V_s \cos\beta a)}{Z_0 \sin \beta a}$$

Therefore, the power at the sending end is given as

$$S_s = P_s + jQ_s = \bar{V}_s \bar{I}_s^*$$

$$= \frac{V_s V_r \sin\delta}{Z_0 \sin\beta a} + j\,\frac{V_s^2 \cos\beta a - V_s V_r \cos\delta}{Z_0 \sin\beta a}$$

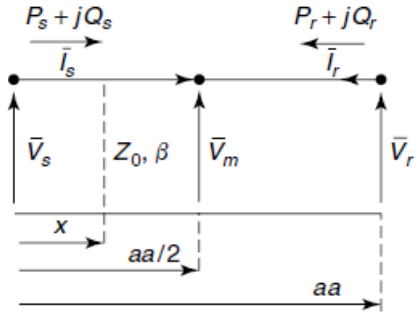


Fig. 4: The Power on a Lossless Distributed Line.

$$S_r = P_r + jQ_r = -\frac{V_s V_r \sin \delta}{Z_0 \sin \beta a} + j \frac{V_r^2 \cos \beta a - V_s V_r \cos \delta}{Z_0 \sin \beta a}$$

Comparing Eqs. and taking the directional notation of Fig. 2.4into account, it is concluded that for a lossless line, Ps c − Pr , as expected. However, Qs & Qr because of the reactive-power absorption generation in the line.

From Eqs, the power flow from the sending end to the receiv- ing end is expressed as

$$P = \frac{V_s V_r \sin \delta}{Z_0 \sin \beta a}$$

In electrically short power lines, where ba is very small, it is possible to make a simplifying assumption that sin ba c ba or Z0 sin ba c Z0 ba c q la, where q la c Xl is the total series reactance of a line. This substitution results in the following well-recognized power equation:

$$P = \frac{V_s V_r}{X_l} \sin \delta$$

Accordingly, the maximum power transfer is seen to depend on the line length. When the power-transfer requirement for a given length of a line increases, higher transmission voltages of V_s and V_r must be selected.

This chapter is not intended to provide a comprehensive analysis of trans- mission lines. Rather, its objective is to examine those aspects that enhance the understanding of the interplay between voltages on the line and the resulting reactive-power flows.

Symmetrical Lines

When the voltage magnitudes at the two ends of a line are equal that is, V_s c V_r c V, and the line is said to be symmetrical. Because power networks operate as voltage sources, attempts are made to hold almost all node voltages at nearly rated values. A symmetrical line, therefore, presents a realistic situation. From Eqs. the following relation- ships are derived:

$$P_s = -P_r = \frac{V^2}{Z_0 \sin \beta a} \sin \delta$$

and

$$Q_s = Q_r = \frac{V^2 \cos \beta a - V^2 \cos \delta}{Z_0 \sin \beta a}$$

Active and reactive powers of a transmission line are frequently normalized by choosing the surge-impedance load (SIL) as the base.

$$\frac{P_s}{P_0} = -\frac{P_r}{P_0} = \frac{\sin \delta}{\sin \beta l}$$

and

$$\frac{Q_s}{Q_0} = \frac{Q_r}{Q_0} = \frac{\cos \beta a}{\sin \beta a} - \frac{\cos \delta}{\sin \beta a}$$

Midpoint Conditions of a Symmetrical Line

The magnitude of the midpoint voltage depends on the power transfer. This voltage influences the line insulation and therefore needs to be well understood. For a symmetrical line where the end voltages are held at nominal values, the midpoint voltage shows the highest magnitude variation. In terms of the midpoint voltage V_m, the receiving-end voltage of a symmetrical line, from Eq. (2.4), is given as

$$\overline{V}_r = \overline{V}_m \cos \frac{\beta a}{2} - jZ_0 \overline{I}_m \sin \frac{\beta a}{2}$$

For simplification, define V_m c $V_m \angle 0^8$ as the reference phasor. Because the line is symmetrical and lossless, that is, P_S c $-P_r$ c P_m c P and Q_m c 0, the midpoint current I_m is given by I_m c PV_m. Under these conditions, can be rewritten as

$$\overline{V}_r = V_m \cos \frac{\beta a}{2} - jZ_0 \frac{P}{V_m} \sin \frac{\beta a}{2}$$

$$V_r^2 = V_m^2 \cos^2 \frac{\beta a}{2} + Z_0^2 \frac{P^2}{V_m^2} \sin^2 \frac{\beta a}{2}$$

Setting $V_r = V_{\text{nom}}$ and $V_{\text{nom}}^2/Z_0 = P_0$, we get

$$\frac{V_r^2}{V_{\text{nom}}^2} = \left(\frac{V_m}{V_{\text{nom}}}\right)^2 \cos^2 \frac{\beta a}{2} + \left(\frac{Z_0}{V_{\text{nom}}^2}\right)^2 P^2 \left(\frac{V_{\text{nom}}}{V_m}\right)^2 \sin^2 \frac{\beta a}{2}$$

If we let $V_m/V_{\text{nom}} = \tilde{V}_m$ (per-unit voltage at the midpoint), then considerng that $(V_r/V_{\text{nom}}) = 1$, we have

$$\tilde{V}_m^4 - \frac{\tilde{V}_m^2}{\cos^2 \frac{\beta a}{2}} + \left(\frac{P}{P_0}\right)^2 \tan^2 \frac{\beta a}{2} = 0$$

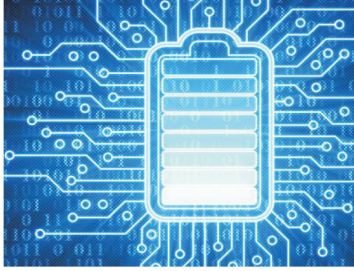
$$\tilde{V} = \left[\frac{1}{2\cos^2 \frac{\beta a}{2}} \pm \sqrt{\frac{1}{4\cos^2 \frac{\beta a}{2}} - \left(\frac{P}{P_0}\right)^2 \tan^2 \frac{\beta a}{2}}\right]^{1/2}$$

Practical Considerations In general, the values of line parameters l and c remain reasonably independent of the transmission voltage. For example, typical values of l and c may lie in the following ranges:

l = the line inductance/km = 0.78–0.98 mH/km

c = the line capacitance/km = 12.1–15.3 nF/km

On the basis of these parameters, the surge impedance, $Z_0 = \sqrt{l/c}$, lies in the range of 225 to 285.

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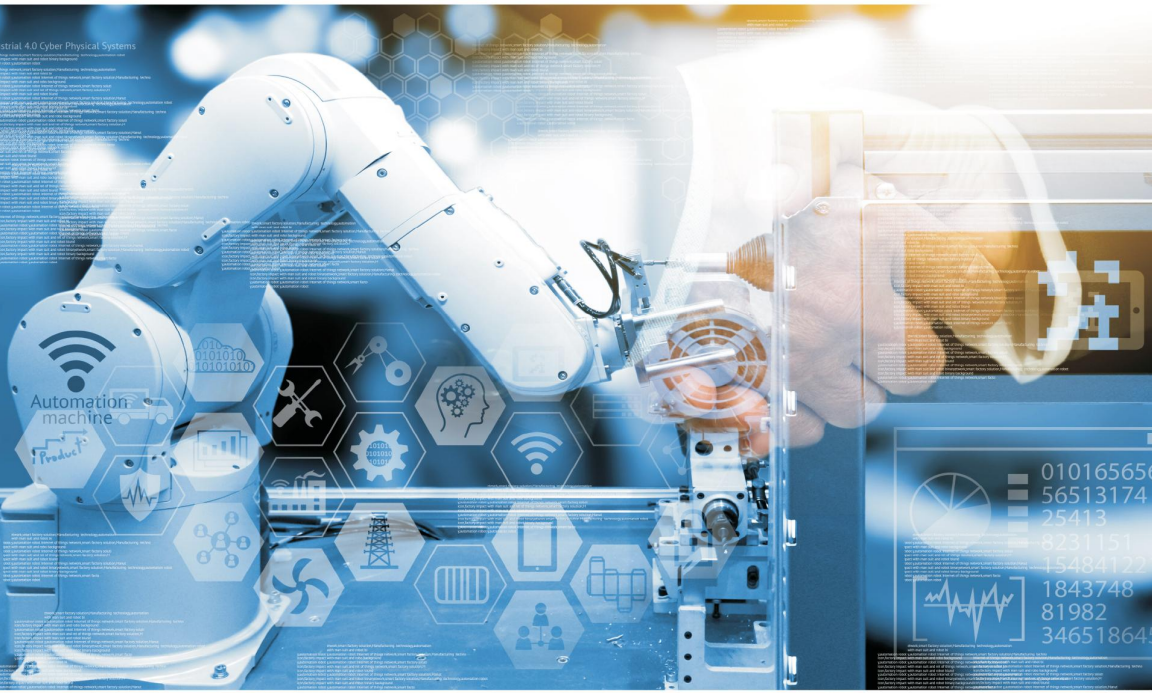

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Contents

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Emerging Facts Controllers

S. Divyapriya[1] , Dr. M. Siva Ramkumar[2], P. Nagaveni[3] , R. Vidhya Lakshmi[4]

Introduction

With the ever-increasing complexities in power systems across the globe and the growing need to provide stable, secure, controlled, economic, and high-qual- ity power—especially so in the derugulated environment—it is envisaged that FACTS controllers will play a critical role in power systems in the future. Major FACTS controllers—SVCs and TCSCs, for instance—have already been dis- cussed in previous chapters. A host of other highly versatile, effective FACTS controllers exist that are fast emerging in power

This chapter presents the operating principles and applications of several highly versatile controllers—the STATCOM, SSSC, and UPFC—without any prejudice to other FACTS controllers. These three FACTS controllers are second-generation types that are based on nonthyristor devices such as gate turn-offs (GTOs) and insulated-gate bipolar transistors (IGBTs).

The Statcom

The STATCOM (or SSC) is a shunt-connected reactive-power compensation device that is capable of generating and□ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general

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a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals. Specifically, the STATCOM considered in this chapter is a voltage-source converter that, from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the cor- responding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor.

A STATCOM can improve power-system performance in such areas as the following:

1. The dynamic voltage control in transmission and distribution systems;
2. the power-oscillation damping in power-transmission systems;
3. the transient stability;
4. the voltage flicker control; and
5. the control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

Furthermore, a STATCOM does the following:

1. it occupies a small footprint, for it replaces passive banks of circuit ele- ments by compact electronic converters;
2. it offers modular, factory-built equipment, thereby reducing site work and commissioning time; and
3. it uses encapsulated electronic converters, thereby minimizing its envi- ronmental impact.

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages—at the fundamental frequency—with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the exist- ing system impedance, and can internally generate reactive (both capacitive and inductive) power .

The Tennessee Valley Authority (TVA) installed the first □100-MVA STAT- COM in 1995 at its Sullivan substation. The application of this STATCOM is expected to reduce the TVA's need for load tap changers, thereby achieving sav- ings by minimizing the potential for transformer

failure. This STATCOM aids in resolving the off-peak dilemma of overvoltages in the Sullivan substation area while avoiding the more labor- and space-intensive installation of an additional transformer bank. Also, this STATCOM provides instantaneous control—and therefore increased capacity—of transmission voltage, providing the TVA with greater flexibility in bulk-power transactions, and it also increases the system reli- ability by damping grids of major oscillations in this grid [12], [13].

To summarize, a STATCOM controller provides voltage support by gener- ating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks.

The Principle of Operation

A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). A single-line STATCOM power circuit is shown in Fig. 1(a), where a VSC is connected to a utility bus through magnetic coupling. In Fig. 1(b), a STATCOM is seen as an adjustable voltage source behind a reactance—meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a STATCOM a com pact design, or small footprint, as well as low noise and low magnetic impact.

The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage, E_S , of the converter, as illustrated in Fig. 1(c). That is, if the amplitude of the output voltage is increased above that of the utility bus voltage, E_t , then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system. If the output voltage equals the ac system voltage, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state.

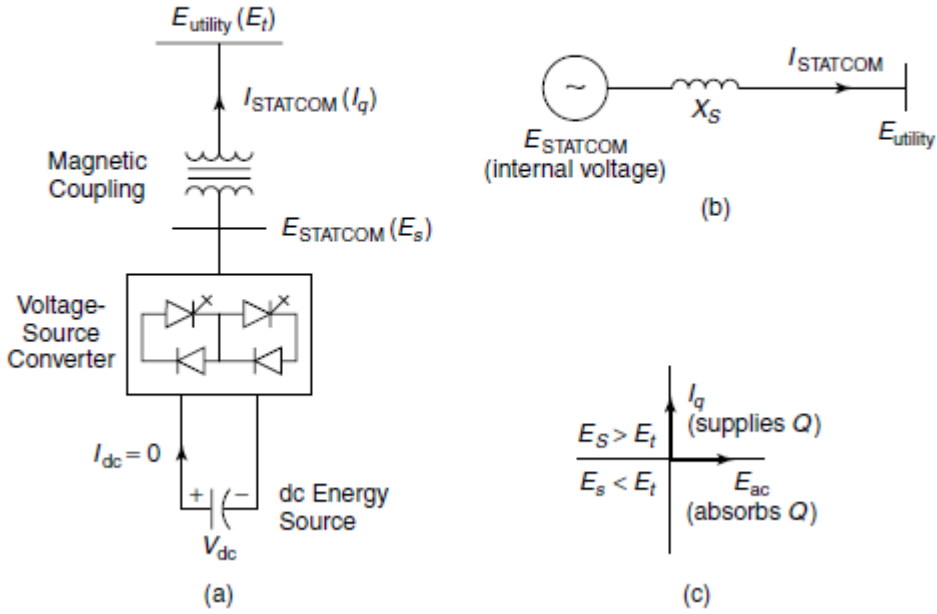


Fig. 1: The STATCOM Principle Diagram: (A) A Power Circuit; (B) An Equivalent Circuit; And (C) A Power Exchange

Adjusting the phase shift between the converter-output voltage and the ac- system voltage can similarly control real-power exchange between the converter and the ac system. In other words, the converter can supply real power to the ac system from its dc energy storage if the converter-output voltage is made to lead the ac-system voltage. On the other hand, it can absorb real power from the ac system for the dc system if its voltage lags behind the ac-system voltage.

A STATCOM provides the desired reactive power by exchanging the instantaneous reactive power among the phases of the ac system. The mechanism by which the converter internally generates and□or absorbs the reactive power can be understood by considering the relationship between the output and input powers of the converter. The converter switches connect the dc-input circuit directly to the ac-output circuit. Thus the net instantaneous power at the ac- output terminals must always be equal to the net instantaneous power at the dc-input terminals (neglecting losses) [11].

Assume that the converter is operated to supply reactive-output power. In this case, the real power provided by the dc source as input to the converter must be zero. Furthermore, because the reactive power

at zero frequency (dc) is by definition zero, the dc source supplies no reactive power as input to the converter and thus clearly plays no part in the generation of reactive-output power by the converter. In other words, the converter simply interconnects the three output terminals so that the reactive-output currents can flow freely among them. If the terminals of the ac system are regarded in this context, the converter establishes a circulating reactive-power exchange among the phases. However, the real power that the converter exchanges at its ac terminals with the ac system must, of course, be supplied to or absorbed from its dc terminals by the dc capacitor.

Although reactive power is generated internally by the action of converter switches, a dc capacitor must still be connected across the input terminals of the converter. The primary need for the capacitor is to provide a circulating-cur- rent path as well as a voltage source. The magnitude of the capacitor is chosen so that the dc voltage across its terminals remains fairly constant to prevent it from contributing to the ripples in the dc current. The VSC-output voltage is in the form of a staircase wave into which smooth sinusoidal current from the ac system is drawn, resulting in slight fluctuations in the output power of the converter. However, to not violate the instantaneous power-equality constraint at its input and output terminals, the converter must draw a fluctuating cur- rent from its dc source. Depending on the converter configuration employed, it is possible to calculate the minimum capacitance required to meet the system requirements, such as ripple limits on the dc voltage and the rated-reactive- power support needed by the ac system.

The VSC has the same rated-current capability when it operates with the capacitive- or inductive-reactive current. Therefore, a VSC having a certain MVA rating gives the STATCOM twice the dynamic range in MVAR (this also contributes to a compact design). A dc capacitor bank is used to support (stabilize) the controlled dc voltage needed for the operation of the VSC.

The reactive power of a STATCOM is produced by means of power-elec- tronic equipment of the voltage-source-converter type. The VSC may be a 2- level or 3-level type, depending on the required output power and voltage [2], [3]. A number of VSCs are combined in a multi-pulse connection to form the STATCOM. In the steady state, the VSCs operate with fundamental-frequency switching to minimize converter losses. However, during transient conditions caused by line faults, a pulse width–modulated (PWM) mode is used to prevent the fault

current from entering the VSCs [2], [3]. In this way, the STATCOM is able to withstand transients on the ac side without blocking.

2.2 The V-I Characteristic

A typical *V-I* characteristic of a STATCOM is depicted in Fig. 10.2. As can be seen, the STATCOM can supply both the capacitive and the inductive com- pensation and is able to independently control its output current over the rated maximum capacitive or inductive range irrespective of the amount of ac-system voltage. That is, the STATCOM can provide full capacitive-reactive power at any system voltage—even as low as 0.15 pu.

The characteristic of a STATCOM reveals another strength of this technology: that it is capable of yielding the full output of capacitive generation almost independently of the system voltage (constant-current output at lower voltages). This capability is particularly useful for situations in which the STATCOM is needed to support the system voltage during and after faults where voltage col- lapse would otherwise be a limiting factor.

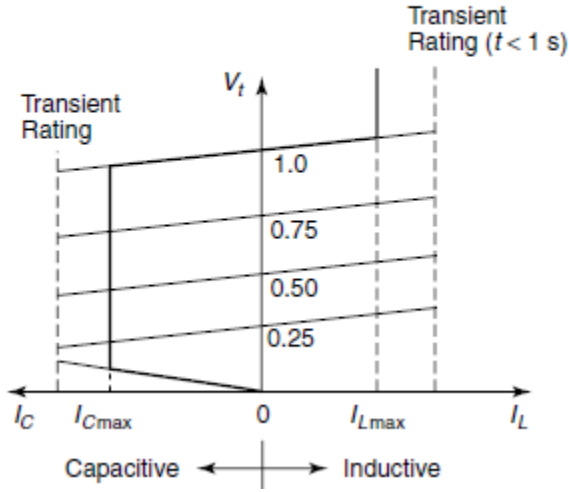


Fig. 2: The *V-I* characteristic of the STATCOM

Figure 2 also illustrates that the STATCOM has an increased transient rat- ing in both the capacitive- and the inductive-operating regions. The maximum attainable transient overcurrent in the capacitive region is determined by the maximum current turn-off capability of the converter switches. In the induc- tive region, the

converter switches are naturally commutated; therefore, the transient-current rating of the STATCOM is limited by the maximum allow- able junction temperature of the converter switches.

In practice, the semiconductor switches of the converter are not lossless, so the energy stored in the dc capacitor is eventually used to meet the internal losses of the converter, and the dc capacitor voltage diminishes. However, when the STATCOM is used for reactive-power generation, the converter itself can keep the capacitor charged to the required voltage level. This task is accomplished by making the output voltages of the converter lag behind the ac-system voltages by a small angle (usually in the 0.1^8–0.2^8 range). In this way, the converter absorbs a small amount of real power from the ac system to meet its internal losses and keep the capacitor voltage at the desired level. The same mechanism can be used to increase or decrease the capacitor voltage and thus, the amplitude of the converter-output voltage to control the var generation or absorption.

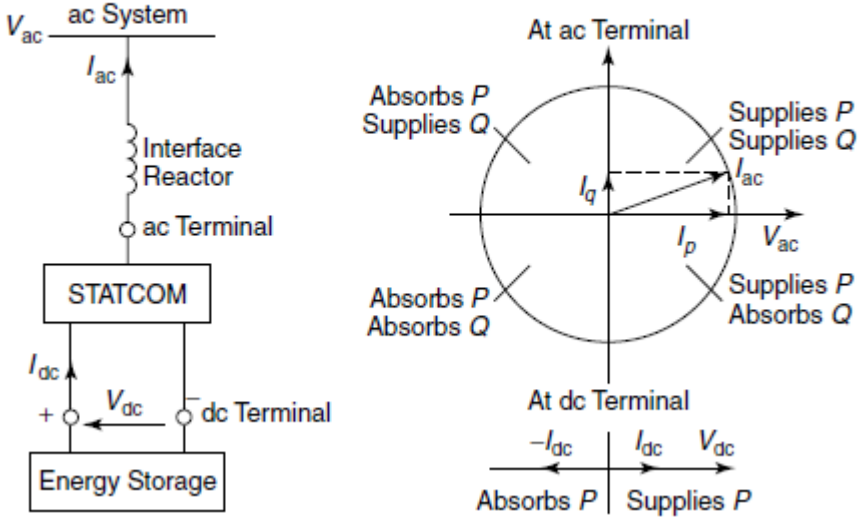


Fig. 3: The Power Exchange Between The STATCOM and The AC System

The reactive- and real-power exchange between the STATCOM and the ac system can be controlled independently of each other. Any combination of real- power generation or absorption with var generation or absorption is achievable if the STATCOM is equipped with an energy-storage device of suitable capacity, as depicted in Fig. 3. With this capability, extremely effective control strategies for the modulation of

reactive- and real-output power can be devised to improve the transient- and dynamic-system-stability limits.

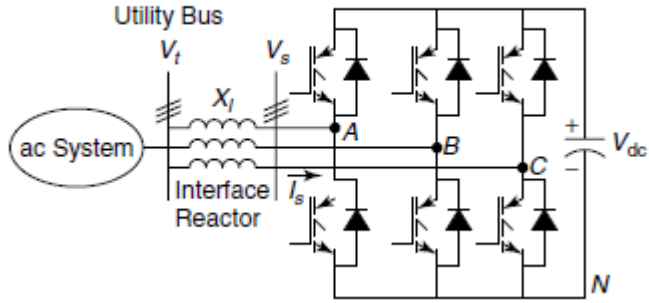


Fig. 4: An Elementary 6-Pulse VSC STATCOM

Harmonic Performance

An elementary 6-pulse VSC STATCOM is shown in Fig. 10.4, consisting of six self-commutated semiconductor switches (IGBT, IGCT, or GTO) with antipar- allel diodes. In this converter configuration, IGBTs constitute the switching devices. With a dc-voltage source (which may be a charged capacitor), the con- verter can produce a balanced set of three quasi-square voltage waveforms of a given frequency by connecting the dc source sequentially to the three output terminals via the appropriate converter switches.

The power quality embraces issues such as voltage flicker, voltage dip, and voltage rise, as well as harmonic performance and high-frequency noise. Power- electronic devices distort voltage and current waveforms in a power network, influencing power facilities and customer equipment in a diverse manner. Har- monic currents induce abnormal noise and parasitic losses, and harmonic volt- ages cause a loss of accuracy in measurement instruments and the faulty oper- ation of relays and control systems. Electromagnetic noise, caused by the noise of the high-frequency electromagnetic waves emitted from power-electronic cir- cuits, affects electronic devices used in business and industry and often induces interfering voltage in communication lines. The corrective measure generally recommended for mitigating harmonics and high-frequency noise is to limit their generation at the source.

In principle, the STATCOM-output voltage wave is a staircase-type wave synthesized from the dc-input voltage with appropriate

combinations of converter switches. For example, the 6-pulse converter shown in Fig. 4 is oper ated typically with either a 120^8 or 180^8 conduction sequence for converter switches. For a 180^8 conduction sequence, three switches conduct at a time; for a 120^8 conduction sequence, two switches conduct at a time. Figure 10.5 shows the 3-step staircase-line voltage, v_{ab} , along with the fundamental com- ponent, V_{fund} , for a conduction sequence of 180^8.

The line voltage v_{ab} , in terms of its various frequency components, can be described by the following Fourier-series equation:

$$v_{ab} = a_0 + \sum_{h=1}^{\infty} a_h \cos(h\omega t) + \sum_{h=1}^{\infty} b_h \sin(h\omega t)$$

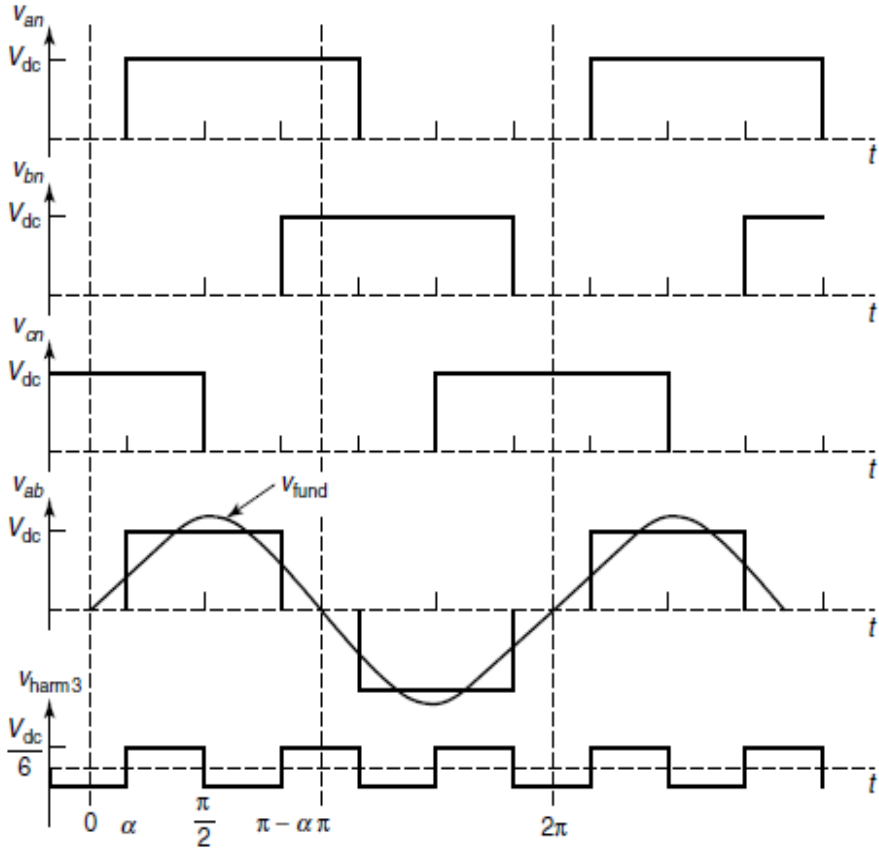


Fig. 5: An ac line-voltage output of a 6-pulse voltage-source inverter for a 180^8 conduction sequence

$$b_h = \frac{2}{\pi} \int_0^{\pi} V_{dc} \sin(h\omega t)\, d(\omega t)$$

$$b_h = \frac{2}{\pi} \int_{\alpha}^{\pi - \alpha} V_{dc} \sin(h\omega t)\, d(\omega t) = \frac{4V_{dc}}{\pi h} \cos(h\alpha)$$

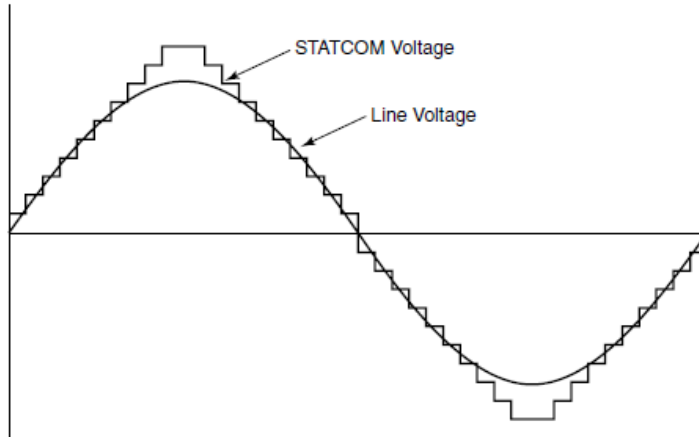
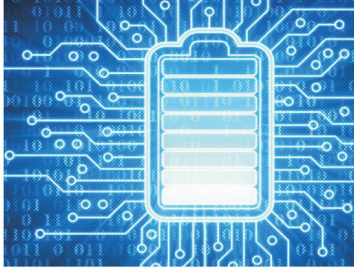


Fig. 6: The Output Voltage of a 48-Pulse STATCOM that Generates Reactive Power.

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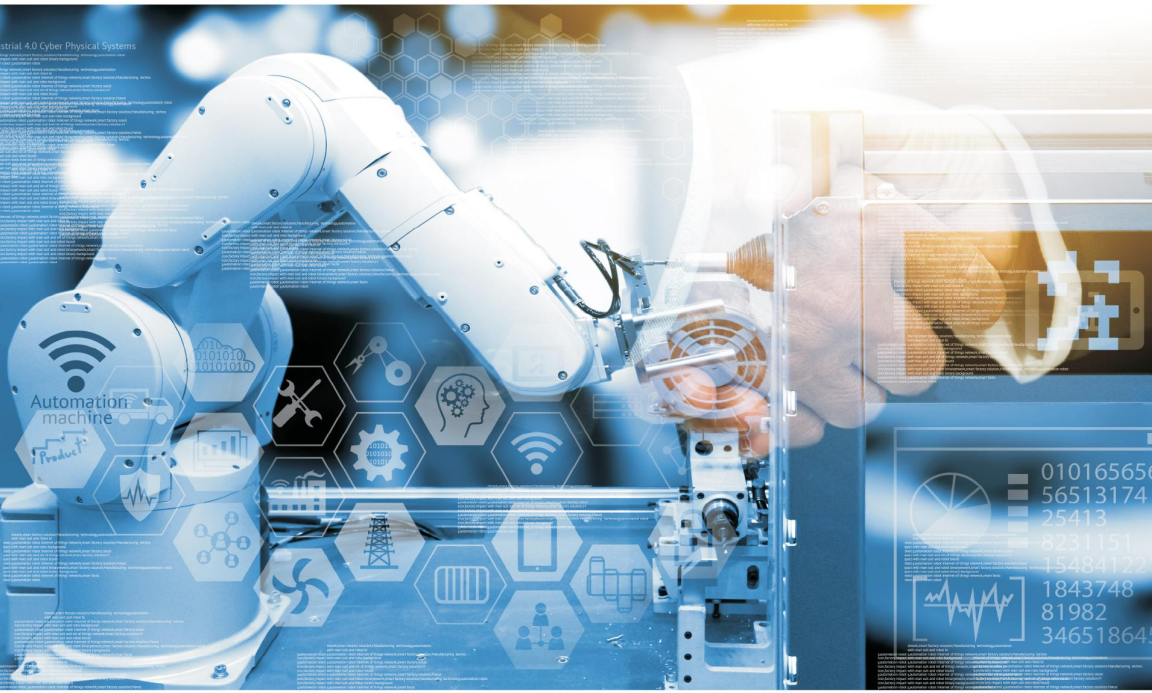

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Fundamental of Measurements and Instrumentation

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Introduction

Functional Elements of Instruments

An Instrument may be defined as a device or a system which is designed to maintain a functional relationship between prescribed properties of physical variables and must include ways and means of communication to a human observer.

Most of the measurement system contains following main functional elements as shown in figure

1. Primary Sensing Element.
2. Variable Conversion Element
3. Variable Manipulation Element
4. Data Transmission Element
5. Data Presentation Element

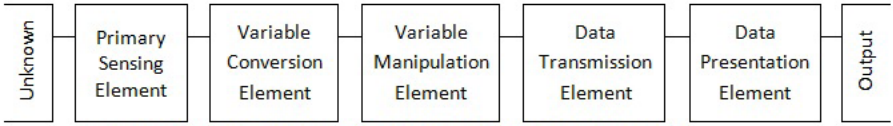

Figure: - Generalized or functional elements of an instrument system

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Primary Sensing Element: - The Measurand is first detected by primary sensing element. The primary sensing element transfers the measurand to variable conversion element for further processing. The output signal of a primary sensing element is a physical variable such as displacement or voltage.

Variable Conversion Element: - The output signal of a primary sensing element may require to be converted to more suitable variables while preserving its information content. This function is performed by variable conversion element and it may be considered as an intermediate transducer

Variable Manipulation Element: - This element is an intermediate stage of a measuring system. It modifies the direct signal by amplification, filtering, etc; so that a desired output is produced the physical nature of the variable remains unchanged during this stage.

Data Transmission Element: - when the functional elements of the measuring system are spatially separated then it becomes necessary to transmit signals from one element to another. This function is performed by data transmission element. It is an essential functional element where remote control operation is desired.

Data Presentation Element: - usually information about the quantity being measured is to be communicated to human observer for monitoring control and analysis purpose. This is therefore, to be presented in form of human sensory capability. This function is done by data presentation element.

Unit of Measurement

A **unit of measurement** is a definite magnitude of a quantity,defined and adopted by convention or by law, that is used as a standard for measurement of the same kind of quantity. Any other quantity of that kind can be expressed as a multiple of the unit of measurement.

Fundamental and physical quantities:

There are 7 physical quantities viz., Length, mass, time, temperature, electric current, luminous intensity and amount of substance.

Length, mass and time are called fundamental physical quantities.

Fundamental and Derived Units

The units of fundamental physical quantities are called fundamental units. They are m, kg and sec. These units can neither be derived from one another nor can be resolved into other units. They are independent to each other.

Units of physical quantities can be expressed in terms of fundamental units and such units are called derived units.

Unit of area can be an example for derived unit. If L is the length of square then L x L = L^2 is its area. Similarly, the volume of a cube is L x L x L = L^3 cubic area. Units of any physical quantity can be derived from its defining equation.

System of Units

Following are the common system of units to measure mass, length and time.

CGS: Fundamental units of length, mass and time are centimetre, gram and second.

MKS: Fundamental units of length, mass and time are metre, kilogram and second. It is a coherent system of units in mechanics.

FPS: Known as British system of units, it is not a metric system. It stands for foot, pound and second. Its use is declining in scientific work.

SI: It is a new system introduced by General Conference of Weights and Measures in 1960. It is called "Le Systeme International d' Unites".

It has seven basic and three supplementary units

Basic physical quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	Second	s
Temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd
Quantity of matter	mole	mol

Supplementary quantities and their units

Physical quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	Steradian	sr
Radioactivity	Curie	ci

Prefixes are used for large and small quantities. The following table gives prefixes, their symbol and their values in powers of 10, as used in SI units.

Prefix	Symbol	Power of 10
deci	d	10^{-1}
deka	da(D)	10^{1}
centi	c	10^{-2}
hecto	h	10^{2}
milli	m	10^{-3}
kilo	k	10^{3}
micro	μ	10^{-6}
mega	M	10^{6}
nano	n	10^{-9}
giga	G	10^{9}
pico	P	10^{-12}
tera	T	10^{12}
femto	f	10^{-15}
peta	P	10^{15}
atto	a	10^{-18}
exa	E	10^{18}
zepta	z	10^{-21}
zetta	Z	10^{21}
yocto	y	10^{-24}
(yotto)	Y	10^{24}

Standard

A standard is a physical representation of a unit of measurement. A known accurate measure of physical quantity is termed as standard. These standards are used to determine the values of other physical quantities by the comparison methods. In fact, a unit is realized by

reference to a material standard or to natural phenomena, including physical and atomic constants.

For example, the fundamental unit of length in the international system (SI) is the meter defined as the distance between two fine lines engraved on gold plugs near the ends of a platinum-iridium alloy at c and mechanically supported in a prescribed manner.

Based on the functions an application. Standards are classified into four categories as

(i) International standards
(ii) Primary standards
(iii) Secondary standards
(iv) Working standards

International standards: International standards are defined by international agreement. They are periodically evaluated and checked by absolute measurement in terms of fundamental units of physics . They represent certain units of measurement to the closest possible accuracy attainable by the science and technology of measurement . These international standards are not available to ordinary users for measurements and calibrations.

International ohms: It is defined as the resistance offered by a column of mercury having a mass of 14.4521gms, uniform cross sectional area and length of 106.300 cm, to the flow at constant current at the melting point of ice.

International Amperes: It is an unvarying current , which when passed through a solution of silver nitrate in water deposits silver at the rate of 0.00111gm/5.

Primary standards: The Principle function of primary standards is the calibration and verification of secondary standards. Primary standards are maintained at the National standards Laboratories in different countries. They are not available for use outside the National Laboratory. These Primary standards are absolute standards of high accuracy that can be used as ultimate reference standard .

Secondary standards: Secondary standards are basic reference standards used by measurement and calibration laboratories in industries. These secondary standards are maintained by the particular industry to which they belong. Each industry has its own secondary standard to the National Standards Laboratory for calibration, the

National Standards Laboratory returns the secondary standards to the particular industrial laboratory with a certification of measuring accuracy in terms of a primary standards.

Working standards: Working standards are the principal tools of a measurement laboratory. These standards are used to check and calibrate laboratory instruments for accuracy and performance for example, manufactures of electronic components Such as capacitors resistors etc. Use a standard called a working standard for checking the component values being manufactured a standard resistor for checking of resistance value manufactured.

Static And Dynamic Characteristics

Static Characteristics

Static characteristics refer to the characteristics of the system when the input is either held constant or varying very slowly. The items that can be classified under the heading static characteristics are mainly:

Range (or span)

It defines the maximum and minimum values of the inputs or the outputs for which the instrument is recommended to use. For example, for a temperature measuring instrument the input range may be 100-500°C and the output range may be 4-20 mA.

Sensitivity

It can be defined as the ratio of the incremental output and the incremental input. While defining the sensitivity, we assume that the input-output characteristic of the instrument is approximately linear in that range. Thus if the sensitivity of a thermocouple is denoted as $10\,\mu V / {}^{0}C$, it indicates the sensitivity in the linear range of the thermocouple voltage vs. temperature characteristics. Similarly sensitivity of a spring balance can be expressed as 25 mm/kg (say), indicating additional load of 1 kg will cause additional displacement of the spring by 25mm. Again sensitivity of an instrument may also vary with temperature or other external factors. This is known as sensitivity drift. Suppose the sensitivity of the spring balance mentioned above is 25 mm/kg at $20^{o}C$ and 27 mm/kg at $30^{o}C$. Then the sensitivity drift/^{o}C is 0.2 (mm/kg)/^{o}C. In order to avoid such sensitivity drift, sophisticated instruments are either kept at controlled temperature, or suitable in-built temperature compensation schemes are provided inside the instrument.

Linearity

Linearity is actually a measure of nonlinearity of the instrument. When we talk about sensitivity, we assume that the input/output characteristic of the instrument to be approximately linear. But in practice, it is normally nonlinear, as shown in Fig.1. The *linearity* is defined as the maximum deviation from the linear characteristics as a percentage of the full scale output.

Hysteresis

Hysteresis exists not only in magnetic circuits, but in instruments also. For example, the deflection of a diaphragm type pressure gage may be different for the same pressure, but one for increasing and other for decreasing.

Resolution

In some instruments, the output increases in discrete steps, for continuous increase in the input. It may be because of the finite graduations in the meter scale; or the instrument has a digital display, as a result the output indication changes discretely.

Accuracy

Accuracy indicates the closeness of the measured value with the actual or true value, and is expressed in the form of the *maximum error (= measured value – true value)* as a percentage of full scale reading. Thus, if the accuracy of a temperature indicator, with a full scale range of 0-500 ^{O}C is specified as ± 0.5%, it indicates that the measured value will always be within ± 2.5 ^{O}C of the true value, if measured through a standard instrument during the process of calibration. But if it indicates a reading of 250 ^{O}C, the error will also be ± 2.5 ^{O}C, i.e. ± 1% of the reading. Thus it is always better to choose a scale of measurement where the input is near full-scale value. But the true value is always difficult to get. We use standard calibrated instruments in the laboratory for measuring true value if the variable.

Precision

Precision indicates the repeatability or reproducibility of an instrument (but does not indicate accuracy). If an instrument is used to measure the same input, but at different instants, spread. Over the whole day, successive measurements may vary randomly. The random fluctuations of readings, (mostly with a Gaussian distribution) are often due to random variations of several other factors which have not been taken into account, while measuring the variable. A precision instrument

indicates that the successive reading would be very close, or in other words, the standard deviation of the set of measurements would be very small. The difference between precision and accuracy needs to be understood carefully. Precision means repetition of successive readings, but it does not guarantee accuracy; successive readings may be close to each other, but far from the true value. On the other hand, an accurate instrument has to be precise also, since successive readings must be close to the true value (that is unique).

Dynamic Characteristics

Dynamic characteristics refer to the performance of the instrument when the input variable is changing rapidly with time. For example, human eye cannot detect any event whose duration is more than one-tenth of a second; thus the dynamic performance of human eye cannot be said to be very satisfactory. The dynamic performance of an instrument is normally expressed by a differential equation relating the input and output quantities. It is always convenient to express the input-output dynamic characteristics in form of a linear differential equation.

Displacement sensors using Potentiometric principle (Fig. 1) have no energy storing elements. The output voltage eg can be related with the input displacement x_i by an algebraic equation:

m = mass of the junction

C = specific heat

h = heat transfer co-efficient

A = surface area of the hot junction.

Hence, the bare thermocouple is a first order sensor. But if the bare thermocouple is put inside a metallic protective well (as it is normally done for industrial thermocouples) the order of the system increases due to the additional energy storing element (thermal mass of the well) and it becomes a second order system.

Dynamic characteristics specifications are normally referred to the referred to the performance of the instrument with different test signals, e.g. Impulse input, step input, ramp input and sinusoidal input. Few important specifications are:

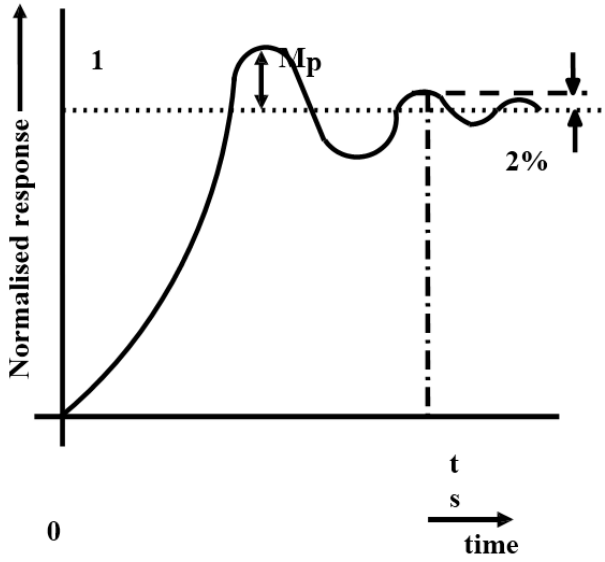
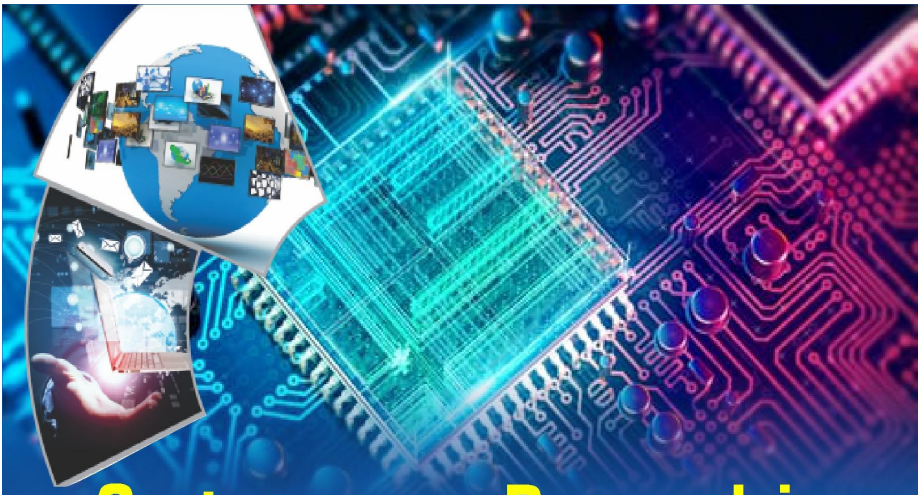


Fig. 1: Step response of a dynamic system

Step Response Performance

The normalized step response of a measurement system normally encountered. Two important parameters for classifying the dynamic response are:

1. ***Peak Overshoot (M_p):*** It is the maximum value minus the steady state value, normally expressed in terms of percentage.
2. ***Settling Time (t_s):*** It is the time taken to attain the response within ± 2% of the steady state value.
3. ***Rise time (t_r):*** It is the time required for the response to rise from 10% to 90% of its final value.



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Electrical Machines DC Generators

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Introduction

An electrical generator converts mechanical energy in the form of rotation of the conductor (armature) into electrical energy, a motor does the opposite. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, or any other source of mechanical energy.

According to Faraday's laws of electromagnetic induction, whenever a conductor is moved in a magnetic field, dynamically induced e.m.f is produced in the conductor. When an external load is connected to the conductor the induced e.m.f causes a current to flow in the load. Thus the mechanical energy given in the form of motion to the conductor is converted into electrical energy.

Construction of a DC Machine

A DC Generator consists of a stationary structure which generates a strong magnetic field, and a set of rotating windings which rotate within that field. On small machines the magnetic field may be provided by a permanent magnet; larger machines have their magnetic field created by electromagnets. In Fig.3.1, DC Generator construction is presented.

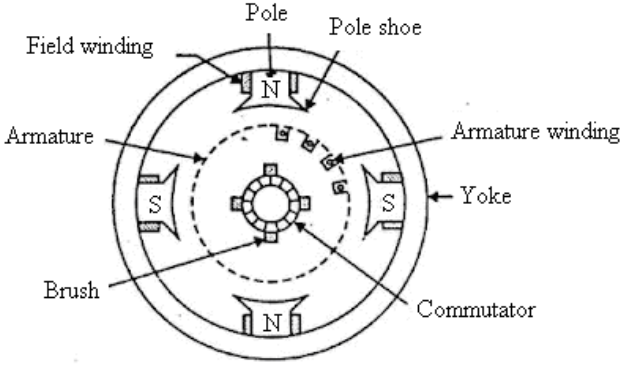


Figure 1: Construction of DC Generator

Basically the construction of a DC machine includes mainly 6 parts. They are:

1) Magnetic Frame (or) Yoke
2) Poles
   - Pole Face (or) Pole Core
   - Pole Shoe
3) Pole Windings (or) Field Windings
4) Armature Core
5) Commutator
6) Brushes and Bearings

i. Magnetic Frame (or) Yoke

It is cylindrical in shape and made out of cast steel or cast iron. It is the outer most part of the DC machine on which the poles are located on the inner side.

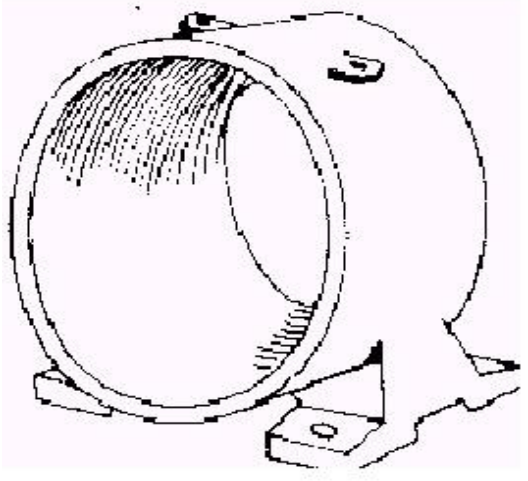


Figure 2: Yoke

Purpose:

1) It gives mechanical support to the poles situated on the inner part of the Yoke.
2) It acts as a protecting layer to the entire DC machine and protects from the atmospheric ailments.
3) It acts as Magnetic Flux carrier in the DC machine.

ii. Poles (Pole Core and Pole Shoe)

Pole Core:

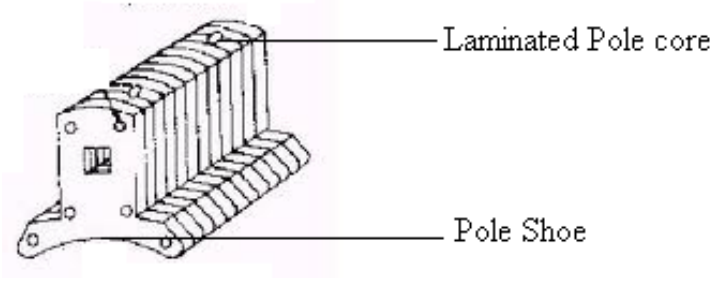


Figure 3: Pole core and Pole shoe

The pole core itself maybe a solid piece made up of either cast iron or cast steel. It supports the exciting coils (or field coils).

Construction:

1) In this method both the pole shoe and pole core are laminated and are riveted permanently under hydraulic pressure.
2) The thickness of each laminated sheet varies from 0.25 mm to 1 mm.
3) All the poles should be fitted on to the Yoke by means of screws inside the pole such that it should enter the Yoke and get fixed.

Pole Shoe:

The field magnet consists of mainly pole shoe and pole core. The pole shoe serves mainly for two purposes.

- In spreading the magnetic flux uniformly in the air gap.
- By increasing the cross-sectional area, reduce the reluctance of the magnetic flux path.

iii. Pole Windings (or) Field Windings

The field coils or pole coils consists of copper wire or strip. When current is passed through these coils the pole becomes an electromagnet and starts establishing a magnetic field in the machine.

iv. Armature Core

1) It is the main part of the DC machine which houses or holds the armature coils or conductors.
2) It is basically cylindrical in shape built by several circular steel disks.
3) Every disk is punched, the punched portion is called as "Slots" and the unpunched portion is called as "Teeth".
4) The slot must be covered with the insulating material mica.
5) The laminations are perforated for air duct which permits the axial flow of air through the armature for cooling purpose.
6) The inner periphery consists of "Keyways" where as the outer periphery consists of "Slots and Teeth".
7) Keyways are used to fix the shaft, which appears as a "Dove- Tailed" or "Wedge – Shaped".

8) When the conductors rotate, they alternatively come under the influence of North and South poles. This causes high hysteresis loss in the armature core. To reduce this loss, armature core is made up of low hysteresis steel containing a few percentage of silicon.

9) When the armature core rotates in the pole flux, eddy currents are also produced in it. This produces unnecessary heat which results in heavy power loss. To minimize the eddy current losses, the armature core is laminated. Inbetween laminations insulation is provided. The laminations are about 0.4mm to 0.5mm thick. The laminations are often known as stampings.

10) The eddy current losses and hysteresis losses produce considerable heat in the armature, and spacers. Ventilating ducts may be necessary to remove this heat. Sometimes a cooling fan is provided at one end of the armature for good ventilation.

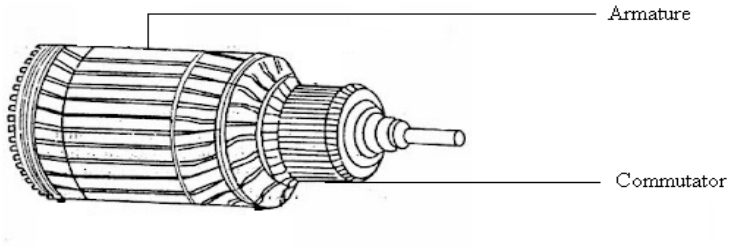


Figure 4: Armature

v. Commutator

1) The shape of a commutator appears to be wedge-shaped and cylindrical structure.

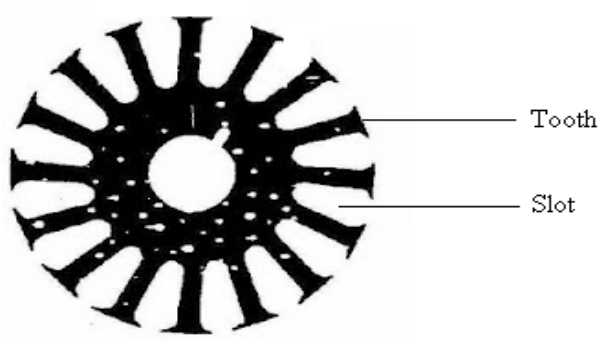


Figure 5: Tooth and Slot

2) The function of the commutator is to facilitate collection of current from the armature conductors or coils.
3) It rectifies i.e., it converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit.
4) The wedge-shaped segments are insulated from each other with the help of thin layers of mica.

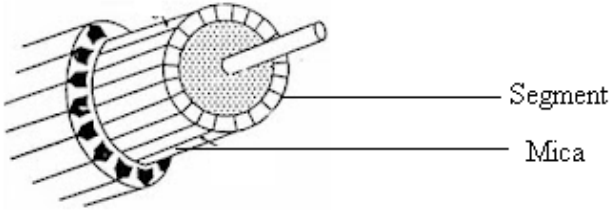


Figure 6: Commutator

vi. Brushes and Bearings

1) The function of Brushes is to collect the current from the commutator, is usually made of carbon or graphite and is in the shape of a rectangular block.

2) These brushes are housed in brush-holders usually of the box-type variety.
3) The brushes are made to bear down on the commutator by a spring whose tension can be adjusted by changing the position of the lever in the notches.
4) A flexible copper wire is mounted at the top of the brush, it conveys current from the brushes to the holder.
5) The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator.
6) Because of the reliability, ball-bearings are frequently employed, though for heavy duties, Roller bearings are most preferred.
7) Sleeve bearings are used which are lubricated by ring oilers fed from oil reservoir in the bearing bracket.

Operation of a DC Machine as a Generator Principle

An Electric Generator is a machine that converts mechanical energy into electrical energy. An electric generator is based on the principle that whenever flux is cut by a conductor, an e.m.f. is induced which will cause a current to flow if the conductor circuit is closed. The direction of induced e.m.f. (and hence current) is given by Fleming's right hand rule. Therefore, the essential components of a generator are:

1) a magnetic field
2) conductor or a group of conductors
3) motion of conductor with respect to the magnetic field.

Simple Loop Generator

Consider a single turn loop ABCD rotating clockwise in a uniform magnetic field with a constant speed as shown in Fig.3.7. As the loop rotates, the flux linking the coil sides AB and CD changes continuously. Hence the e.m.f. induced in these coil sides also changes but the e.m.f. induced in one coil side adds to that induced in the other.

1) When the loop is in position no. 1 [See Fig. 3.7], the generated e.m.f. is zero because the coil sides (AB and CD) are cutting no flux but are moving parallel to it.
2) When the loop is in position no. 2, the coil sides are moving at an angle to the flux and, therefore, a low e.m.f. is generated as indicated by point 2 in Fig.3.8.
3) When the loop is in position no. 3, the coil sides (AB and CD) are at right angle to the flux and are, therefore, cutting the flux at a maximum rate. Hence at this instant, the generated e.m.f. is maximum as indicated by point 3 in Fig. 3.8.
4) At position 4, the generated e.m.f. is less because the coil sides are cutting the flux at an angle.
5) At position 5, no magnetic lines are cut and hence induced e.m.f. is zero as indicated by point 5 in Fig. 3.8.
6) At position 6, the coil sides move under the poles of opposite polarity and hence the direction of generated e.m.f. is reversed. The maximum e.m.f. in this direction (i.e., reverse direction, See Fig.3.8 will be when the loop is at position 7 and zero when at position 1. This cycle repeats with each revolution of the coil.

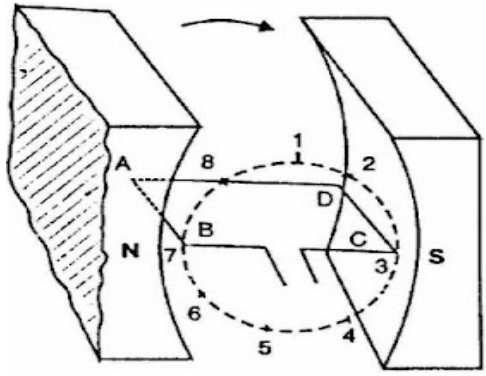


Figure 7: Single loop generator

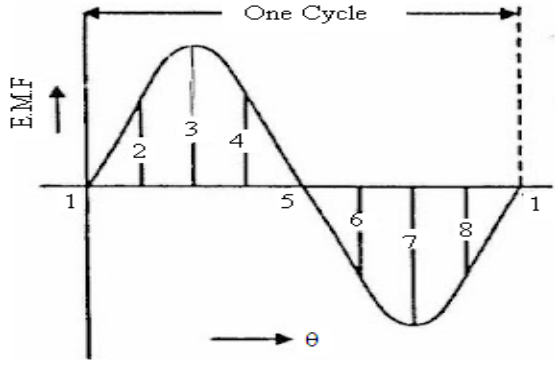


Figure 8: Generated emf in armature

Note: That e.m.f. generated in the loop is alternating one. It is because any coil side, say AB has e.m.f. in one direction when under the influence of N-pole and in the other direction when under the influence of S-pole. If a load is connected across the ends of the loop, then alternating current will flow through the load. The alternating voltage generated in the loop can be converted into direct voltage by a device called commutator. We then have the d.c. generator. In fact, a commutator is a mechanical rectifier.

Action of Commutator

If, somehow, connection of the coil side to the external load is reversed at the same instant the current in the coil side reverses, the current through the load will be direct current. This is what a commutator does. Fig.3.9 shows a commutator having two segments C_1 and C_2. It consists of a cylindrical metal ring cut into two halves C_1 and C_2 respectively separated by a thin sheet of mica. The commutator is mounted on but insulated from the rotor shaft. The ends of coil sides AB and CD are connected to the segments C_1 and C_2 respectively as shown in Fig. 3.10. Two stationary carbon brushes rest on the commutator and lead current to the external load. With this arrangement, the commutator at all times connects the coil side under South pole to the positive brush and that under North pole to the negative brush.

(i) In Fig. 3.10 (a), the coil sides AB and CD are under North pole and South pole respectively. Note that segment C_1 connects the coil side AB to point P of the load resistance R and the segment C_2 connects the coil side CD to point Q of the load. Also note the direction of current through the load, it is from Q to P.

(ii) After half a revolution of the loop (i.e., 180° rotation), the coil side AB is under S-pole and the coil side CD under N-pole as shown in Fig. 3.10 (b). The currents in the coil sides now flow in the reverse direction but the segments C_1 and C_2 have also moved through 180° i.e., segment C_1 is now in contact with positive brush and segment C_2 in contact with negative brush. Note that commutator has reversed the coil connections to the load, i.e., coil side AB is now connected to point Q of the load and coil side CD to the point P of the load. Also note the direction of current through the load, it is again from Q to P.

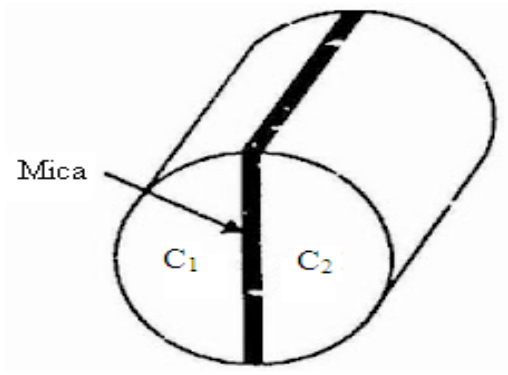
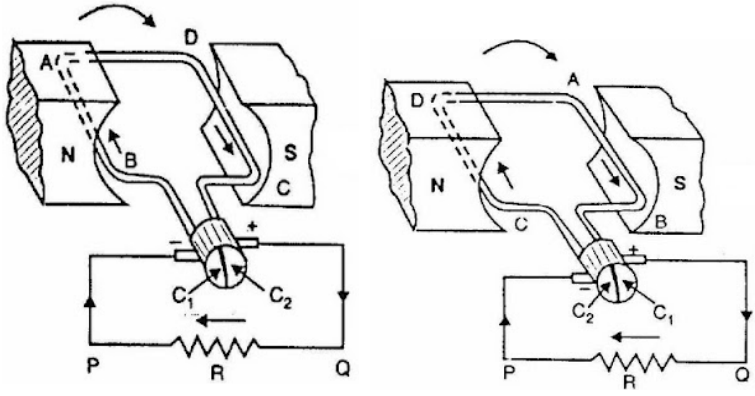


Figure 9: Split rings



(a) (b)

Figure 10: Operation of Commutator

Thus the alternating voltage generated in the loop will appear as direct voltage across the brushes. The reader may note that e.m.f. generated in the armature winding of a d.c. generator is alternating one. It is by the use of commutator that we convert the generated alternating e.m.f. into direct voltage.

The purpose of brushes is simply to lead current from the rotating loop or winding to the external load. The variation of voltage across the brushes with the angular displacement of the loop will be as shown in Fig. 3.11. This is not a steady direct voltage but has a pulsating character. It is because the voltage appearing across the brushes varies from zero to maximum value and back to zero twice for each revolution of the loop.

A pulsating direct voltage such as the one produced by a single loop is not suitable for many commercial uses, what we require is the steady direct voltage. This can be achieved by using a large number of coils connected in series. The resulting arrangement is known as armature winding.

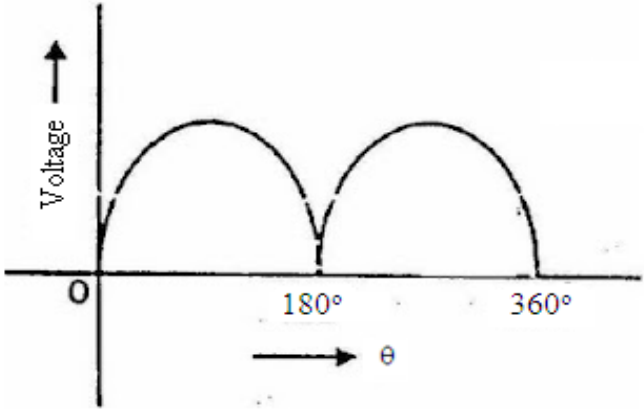


Figure 3.11: Unidirectional output

Generated Emf or Emf Equation of a DC Generator

Generator works on the principle of Faraday's laws of Electromagnetic Induction i.e. when a revolving armature conductor cuts the magnetic lines of flux, a dynamically

induced emf is produced in the armature coil and this emf causes current flow in the rotor circuit it if is closed.

Let

Φ = flux per pole in Weber

Z = total number of armature conductors

P = number of poles

A = number of parallel paths

N = speed of armature in r.p.m.

E_g = emf generated in a parallel path

Flux cut by one conductor in one revolution of the armature, $d\Phi = P \times \Phi$ webers

Time taken to complete one revolution,

$dt = 60/N$ second

e.m.f generated per conductor = $d\Phi/dt$

$= P\Phi N / 60$ volt

e.m.f induced in the generator, E_g = (e.m.f per conductor) x No. of conductor in series per parallel path

$= P\Phi NZ / 60A$ volt

where, A = 2 for wave winding and A = P for lap winding

Types of D.C. Generators

The magnetic field in a d.c. generator is normally produced by electromagnets rather than permanent magnets. Generators are generally classified according to their methods of excitation. On this basis, d.c. generators are divided into the following two classes:

(a) Separately excited d.c. generators

(b) Self-excited d.c. generators

The behaviour of a d.c. generator on load depends upon the method of field excitation adopted.

(a) Separately Excited D.C. Generators

A d.c. generator whose field magnet winding is supplied from an independent external d.c. source (e.g., a battery etc.) is called a separately excited generator. Fig. (3.12) shows the connections of a separately excited generator. It may be noted that separately excited d.c. generators are rarely used in practice.

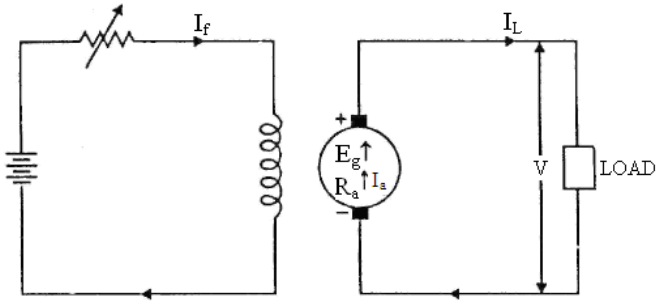


Figure 12: Separately Excited D.C. Generators

Armature current, $I_a = I_L$

Terminal voltage, $V = E_g - I_a R_a$

Electric power developed = $E_g I_a$

Power delivered to the load = $E_g I_a - I_a^2 R_a = I_a (E_g - I_a R_a) = VI_a$

(b) Self-Excited D.C. Generators

A d.c. generator whose field winding is supplied current from the output of the generator itself is called a self-excited generator. There are three types of self-excited generators

depending upon the manner in which the field winding is connected to the armature, namely;

(1) Series generator

(2) Shunt generator and

(3) Compound generator

(1) Series generator

In a series wound generator, the field winding is connected in series with the armature winding so that whole armature current flows through the field winding as well as the load. Fig. (3.13) shows the connections of a series wound generator. Since the field winding carries the whole of load current, it has a few turns of thick wire having low resistance. Series generators are rarely used except for special purposes e.g., boosters.

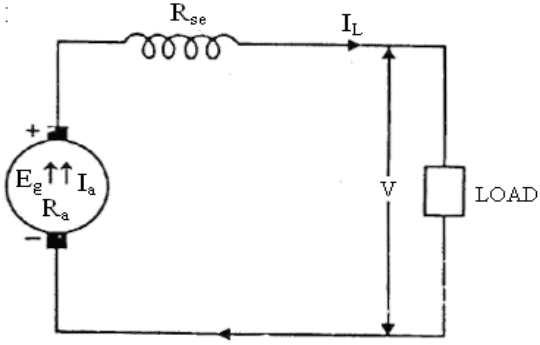


Figure 13: Series Generator

From the figure,

Armature current, $I_a = I_{se} = I_L = I$

Terminal voltage, $V = E_g - I(R_a + R_{se})$

Power developed in armature = $E_g I_a$

Power delivered to the load = $E_g I_a - I_a^2(R_a + R_{se}) = I_a [E_g - I_a(R_a - R_{se})] = VI_a$

(2) Shunt generator

In a shunt generator, the field winding is connected in parallel with the armature winding so that terminal voltage of the generator is applied across it. The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of the armature current flows through the shunt field winding and the rest flows through the load. Fig. (3.14) shows the connections of a shunt-wound generator.

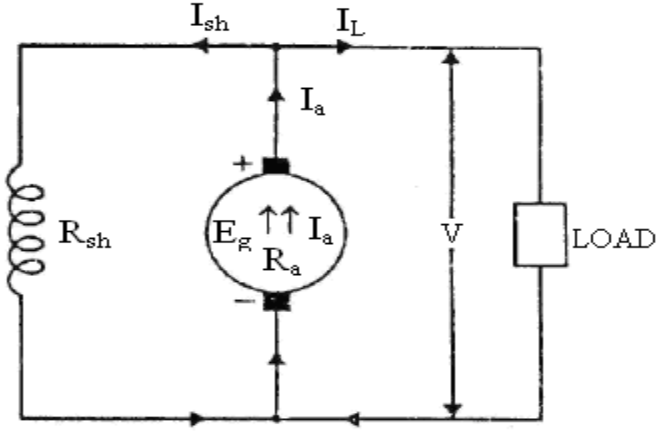


Figure 14: Shunt **Generator**

From the figure,

$$\text{Shunt field current, } I_{sh} = \frac{V}{R_{sh}}$$

Terminal voltage, $V = E_g - I_a R_a$

Power developed in the armature = $E_g I_a$

Power delivered to the load = VI_L

(iii) Compound generator

In a compound-wound generator, there are two sets of field windings—one is in series and the other in parallel with the armature. A compound wound generator may be: (a) Short Shunt, in which only shunt field winding is in parallel with the armature winding [Fig.3.15]. (b) Long Shunt, in which shunt field winding is in parallel with the series combination of series field and armature winding [Fig.3.16].

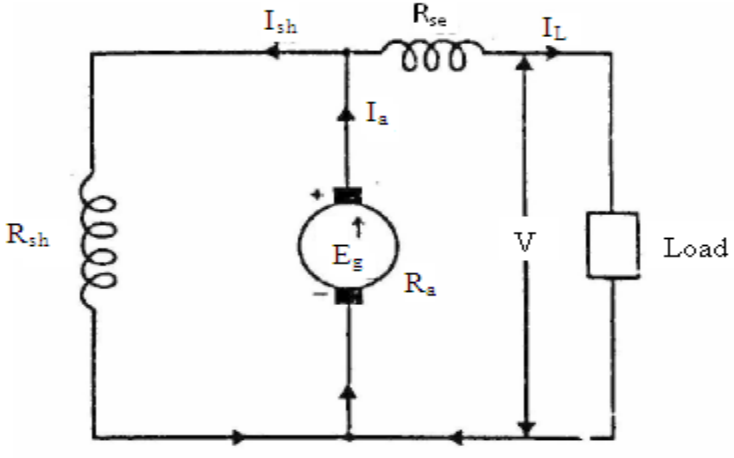


Figure 15: Short Shunt Compound generator

Short shunt:

From the Fig. 3.15,

Series field current, $I_{se} = I_L$

$$\text{Shunt field current, } I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}}$$

Terminal voltage, $V = E_g - I_a R_a - I_{se} R_{se}$

Power developed in the armature = $E_g I_a$

Power delivered to the load = VI_L

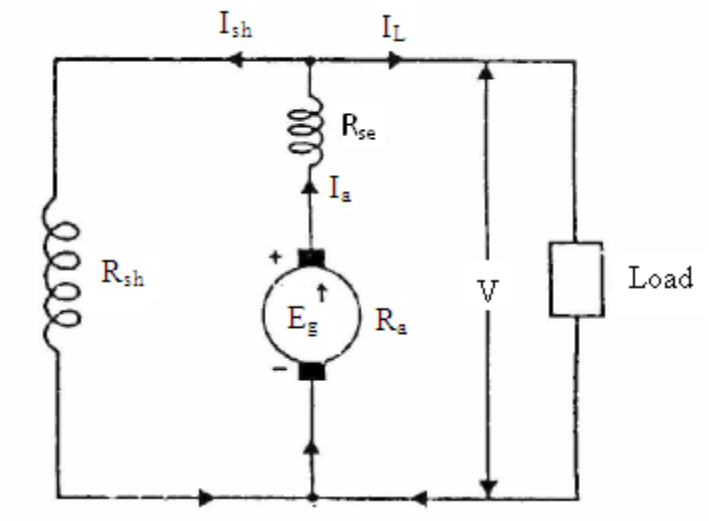


Figure 16: Long Shunt Compound generator

Long shunt:

From the Fig. 3.16,

Series field current, $I_{se} = I_a = I_L + I_{sh}$

$$\text{Shunt field current, } I_{sh} = \frac{V}{R_{sh}}$$

Terminal voltage, $V = E_g - I_a (R_a + R_{se})$

Power developed in the armature = $E_g I_a$

Power delivered to the load = $V I_L$

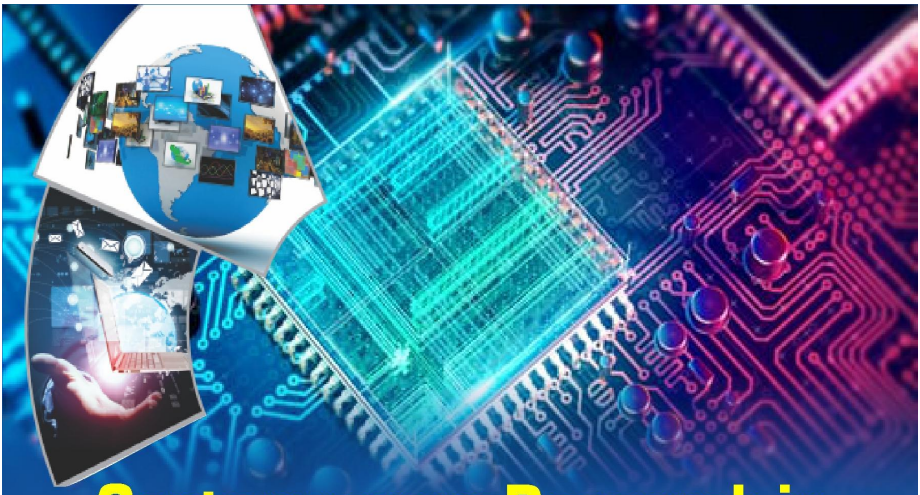
Brush Contact Drop

It is the voltage drop in the brush contact resistance, when current flows. Obviously, its value will depend upon

the amount of current flowing and the value of contact resistance. This drop is generally small.

Application of DC Generators

1) DC supply has for almost all applications been replaced by alternating current. A.C. has the chief advantage that the voltage level can be easily stepped up or down. However, D.C. is in use for some special applications and where the DC equipment purchased is still in operation.
2) Shunt generators are used for supplying nearly constant loads. They are used for battery charging, for supplying the fields of synchronous machines and separately excited d.c. machines.
3) Since the output voltage of a series generator increases with load, series generators are ideal for use as boosters for adding a voltage to the transmission line to compensate for the line drop. The series generator is connected in series with the line and operated in the straight line portion (unsaturated) of the characteristic.
4) Compound generators maintain better voltage regulation and hence finds its application where constancy of voltage is required.



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Measuring Instruments

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Introduction

Measurements are the basic means of acquiring knowledge about the parameters and variables involved in the operation of a physical system. Measurement generally involves using an instrument as a physical means of determining a quantity or variable. An instrument or a measuring instrument is, therefore, defined as a device for determining the value or magnitude of a quantity or variable. The electrical measuring instrument, as its name implies, is based on electrical principles for its measurement function.

These days a number of measuring instruments, both analog as well as digital ones, are available for the measurement of electrical quantities like voltage, current, power, energy, frequency, power factor, etc. The instruments considered in this book are analog devices in which the output or display is a continuous-time signal and bears a fixed relationship to the input.

Analog instruments may be divided into three groups:

1) Electromechanical instruments;
2) Electronic instruments which are often constructed by the addition of electronic circuits to electromechanical indicators thus increasing their sensitivity and input impedances; and
3) Graphical instruments which are electromechanical and electronic instruments having a modified display arrangement so that a graphical trace, that is, a display of instantaneous values against time is obtained.

Definitions of Important Terms

Measurement work employs a number of terms which are defined below:

1) Measurand or Measurement Variable: The quantity or variable being measured is called measurand or measurement variable.

2) Accuracy: It is defined in terms of the closeness with which an instrument reading approaches the true or expected (desired) value of the variable being measured.

3) Precision: It is a measure of the consistency of reproducibility (repeatability) of the measurement (i.e., the successive reading do not differ). For a

given fixed value of an input variable, precision is a measure of the degree to which successive measurement differ from one another.

4) **Sensitivity:** It is defined by the change in the output or response of the instrument for a unit Change of input or measured variable.

5) **Resolution:** Resolution is the smallest change in the measured variable (or measurand) to which the instrument will respond.

6) **True or Expected Value:** The true or expected value of a quantity to be measured may be defined as the average of an infinite number of measured values when the average deviation due to the various contributing factors tends to zero. It also refers to a value of the quantity under consideration that would be obtained by a method (known as exemplar method) agreed upon by experts. In other words, it is the most probable value that calculations indicate and one should expect to measure.

   Note that the value of the unknown obtained by making use of primary standards and measuring instruments is considered to be its true value.

7) **Error:** It is the deviation of the measured (or indicated) value from the true (or expected) value of a quantity. In other words, error is the difference between the measured value and the true value of the unknown quantity. It is also called absolute error or maximum possible error. The error of measurements is given by

   $\epsilon_A = A_m - A_t$

   where A_m = measured value of the quantity

   A_t = true value of the quantity

8) **Correction:** The difference between the true value and the measured value of the sought quantity is defined as the reading correction or simply correction. That is, correction is negative of error. Thus,

   $dC = - \epsilon_A = A_t - A_m$

   Therefore addition of correction in measured value gives the true (or accurate or expected) value.

9) **Bandwidth:** The bandwidth of an instrument relates to the maximum range of frequency over which it is suitable for use. It is normally quoted in terms of 3 decibel (dB) point.

Classification of Measuring Instruments

Electrical measuring instruments may be classified into two groups:

(a) Absolute (or primary) instruments.

(b) Secondary instruments.

(a) Absolute Instruments

- These instruments give the value of the electrical quantity in terms of absolute quantities (or some constants) of the instruments and their deflections.
- In this type of instruments no calibration or comparison with other instruments is necessary.
- They are generally not used in laboratories and are seldom used in practice by electricians and engineers. They are mostly used as means of standard measurements and are maintained by national laboratories and similar institutions.

Some of the examples of absolute instruments are:

- Tangent galvanometer

- Raleigh current balance
- Absolute electrometer.

(b) Secondary Instruments

- They are direct reading instruments. The quantity to be measured by these instruments can be determined from the deflection of the instruments.
- They are often calibrated by comparing them with either some absolute instruments or with those which have already been calibrated.
- The deflections obtained with secondary instruments will be meaningless until it is not calibrated.
- These instruments are used in general for all laboratory purposes.
- Some of the very widely used secondary instruments are: Ammeters, Voltmeter, Wattmeter, Energy meter (watt-hour meter), Ampere-hour meters, etc.

Classification of Secondary Instruments

(a) Classification based on the various effects of electric current (or voltage) upon which their operation depend. They are:

- Magnetic effect: Used in Ammeters, Voltmeters, Wattmeters, Integrating meters etc.
- Heating effect: Used in Ammeters and Voltmeters.
- Chemical effect: Used in DC Ampere hour meters.
- Electrostatic effect: Used in Voltmeters.
- Electromagnetic induction effect: Used in AC Ammeters, Voltmeters, Wattmeters and Integrating meters. Generally the magnetic effect and the electromagnetic induction effect are utilized for the

construction of the commercial instruments. Some of the instruments are also named based on the above effect such as electrostatic voltmeter, induction instruments, etc.

(b) Classification based on the Nature of their Operations

- **Indicating instruments:** Indicating instruments indicate, generally the quantity to be measured by means of a pointer which moves on a scale. Examples are Ammeter, Voltmeter, Wattmeter, etc.
- **Recording instruments:** These instruments record continuously the variation of any electrical quantity with respect to time. In principle, these are indicating instruments but so arranged that a permanent continuous record of the indication is made on a chart or dial. The recording is generally made by a pen on a graph paper which is rotated on a dice or drum at a uniform speed. The amount of the quantity at any time (instant) may be read from the traced chart. Any variation in the quantity with time is recorded by these instruments. Any electrical quantity like current, voltage, power, etc., (which may be measured by the indicating instruments) may be arranged to be recorded by a suitable recording mechanism.
- **Integrating instruments:** These instruments record the consumption of the total quantity of electricity, energy, etc., during a particular period of time. That is, these instruments totalize events over a specified period of time. No indication of the rate or variation or the amount at a particular instant are available from them. Some widely used integrating instruments are: Ampere-hour meter: kilowatt-hour (kWh) meter, kilovolt-ampere-hour (kVARh) meter.

(c) Classification based on the type of Current that can be measured

- Direct Current (DC) instruments
- Alternating Current (AC) instruments
- Both Direct Current and Alternating Current instruments (DC / AC instruments)

Essential Features of Indicating Instruments

We will first consider various torques acting on its moving system. In an indicating instrument, it is essential that the moving system is acted upon by three distinct torques (or forces) for satisfactory working. There torques are:

1) Deflecting or Operating torque, T_d
2) Controlling torque, T_c
3) Damping torque, T_v

1. Deflecting (or Operating) Torque

The deflecting torque, causes the moving system of the instrument to move from its zero position. It may be produced by utilizing any one of the effects of current or voltage in the instrument such as magnetic effect, electromagnetic induction effect, heating effect, electrostatic effect, etc. The actual method of producing a deflecting torque depends upon the type of the instrument. Thus deflecting system of an instrument converts the electric current or potential difference into a mechanical force called deflecting torque.

2. Controlling Torque

The controlling torque developed in an instrument has two functions:

- It limits the movement of the moving system and ensures that the magnitude of the deflections always remains the same for a given value of the quantity to be measured.
- It brings back the moving system to its zero position where the quantity being measured is removed or made zero.

The controlling torque is dependent on the magnitude of deflection produced. The moving system is deflected from zero to such a position that the controlling torque at that deflected position is equal to the deflecting torque. The controlling torque increases in magnitude with the deflection till it balances the deflecting torque. That is, for a steady deflection,

Controlling torque, Tc = Deflection or operating torque, Td

The controlling torque is created in all commercial instruments by any one of the following ways.

- By means of one or two coiled springs. The corresponding instrument is termed spring controlled instruments (mostly used system).
- By the action of gravity due to suitably placed weights on the moving system. Such instruments are known as gravity controlled instruments.

(a) Spring Control

Fig. 4.1 shows a spindle free to turn between two pivots. The moving system is attached to the spindle. Two phosphor-bronze hair springs A and B wound in opposite directions are also shown whose inner ends are attached to the spindle. The outer end of spring A is connected to a lever which is pivoted, the adjustment of which gives zero setting. However, the outer end of B is fixed.

When the pointer is deflected one spring unwinds itself while the other is twisted. This twist in the spring produces restoring or controlling torque, which is proportional to the angle of deflection of the moving system.

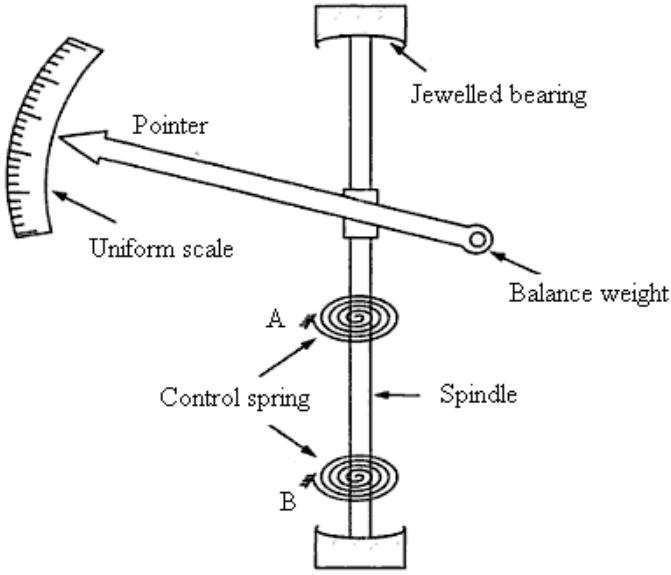

Figure 1: Spring Control

(b) Gravity Control

In gravity controlled instruments, as shown in Fig. 4.2 a small adjustable weight is attached to the spindle of the moving system such that the deflecting torque produced by the instrument has to act against the action of gravity. Thus a controlling torque is obtained. This weight is called the control weight. Another adjustable weight is also attached is the moving system for zero adjustment and balancing purpose. This weight is called Balance weight.

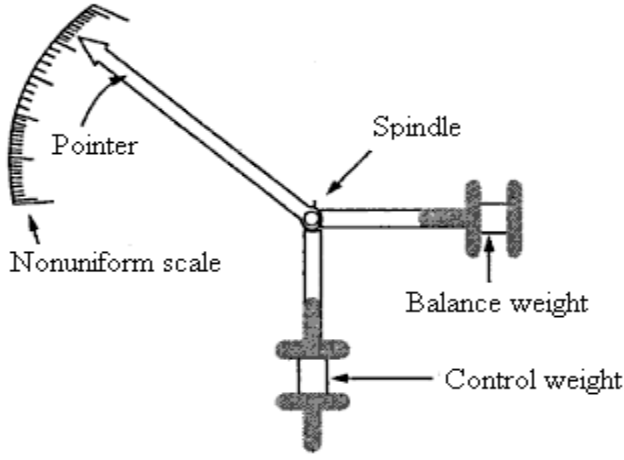

Figure 2: Gravity Control

Damping Torque

We have already seen that the moving system of the instrument will tend to move under the action of the deflecting torque. But on account of the control torque, it will try to occupy a position of rest when the two torques are equal and opposite. However, due to inertia of the moving system, the pointer will not come to rest immediately but oscillate about its final deflected position as shown in Figure 3 and takes appreciable time to come to steady state.

To overcome this difficulty a damping torque is to be developed by using a damping device attached to the moving system. The damping torque is proportional to the speed of rotation of the moving system.

1) **Under damped condition:** The response is oscillatory
2) **Over damped condition:** The response is sluggish and it rises very slowly from its zero position to final position.

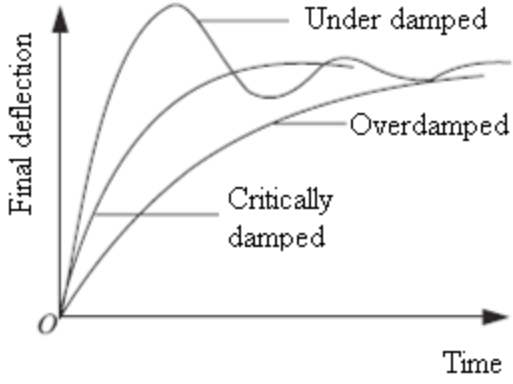

Figure 3: Dynamic response of a measuring instrument

3) Critically damped condition: When the response settles quickly without any oscillation, the system is said to be critically damped.

The damping torque is produced by the following methods:

(a) Air Friction Damping

In this type of damping a light vane or vanes having considerable area is attached to the moving system to develop a frictional force opposing the motion by reason of the air they displace. Two methods of damping by air friction are depicted in Fig. 4.

- The arrangement shown in Fig. 4.4(a) consists of a light aluminium vane which moves in a quadrant (sector) shaped air chamber. The chamber also carries a cover plate at the top. The vane is mounted on the spindle of the moving system. The aluminium vane should not touch the air-chamber walls otherwise a serious error in the deflection of the instrument will be introduced. Now, with the motion, the vane

displaces air and thereby a damping force is created on the vane that produces a torque (damping) on the spindle. When the movement is quicker the damping force is greater; when the spindle is at rest, the damping force is zero.

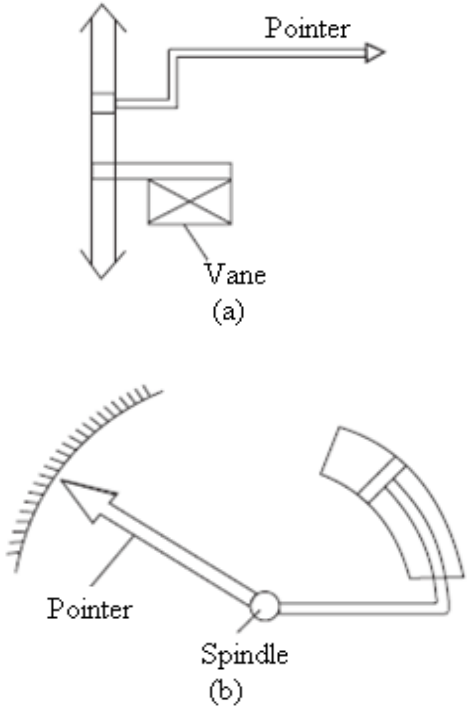

Figure 4: Air Friction Damping

- The arrangement of Fig. 4 (b) consists of a light aluminium piston which is attached to the moving system. This piston moves in a fixed chamber which is closed at one end. Either circular or rectangular chamber may be used. The clearance (or gap) between the piston and chamber walls should be

uniform throughout and as small as possible. When the piston moves rapidly into the chamber the air in the closed space is compressed and the pressure of air thus developed opposes the motion of the piston and thereby the whole moving system. If the piston is moving out of the chamber, rapidly, the pressure in the closed space falls and the pressure on the open side of the piston is greater than that on the opposite side. Motion is thus again opposed. With this damping system care must be taken to ensure that the arm carrying the piston should not touch the sides of the chamber during its movement. The friction which otherwise would occur may introduce a serious error in the deflection.The air friction damping is very simple and cheap. But care must be taken to ensure that the piston is not bent or twisted. This method is used in moving iron and hot wire instruments.

(b) Fluid Friction Damping

- This form of damping is similar to air friction damping. The action is the same as in the air friction damping. Mineral oil is used in place of air and as the viscosity of oil is greater, the damping force is also much greater. The vane attached to the spindle is arranged to move in the damping oil.
- It is rarely used in commercial type instruments.

Two arrangements of fluid damping are shown in Fig. 5.

1) In Fig. 4.5(a) a disc attached to the moving system is immersed in the fluid (damping oil). When the moving system moves the disc moves in oil and a frictional drag is produced. For minimizing the surface tension affect, the suspension stem of the disc should be cylindrical and of small diameter.

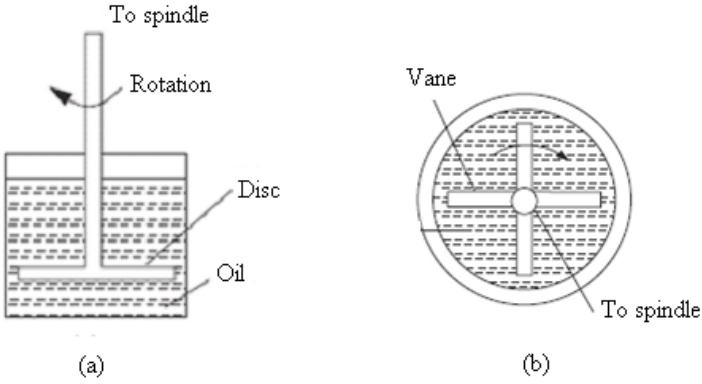

Figure 5: Fluid Friction Damping

2) In the arrangement of Fig. 5 (b) a number of vanes are attached to the spindle. These vanes are submerged in oil and moves in a vertical plane. This arrangement provides greater damping torque.

3) The oil used must fulfill the following requirements.
   - It should not evaporate quickly
   - It should not have any corrosive effect on metals.
   - Its viscosity should not change appreciably with temperature.
   - It should be a good insulator.

(c) Eddy Current Damping

Eddy current damping is the most efficient form of damping. The essential components in this type of damping are a permanent magnet; and a light conducting disc usually of alumninum.

When a sheet of conducting material moves in a magnetic field so as to cut through lines of force, eddy currents are set up in it and a force exists between these currents and the magnetic field, which is always in the direction opposing

the motion. This force is proportional to the magnitude of the current, and to the strength of field. The former is proportional to the velocity of movement of the conductor, and thus, if the magnetic field is constant, the damping force is proportional to the velocity of the moving system and is zero when there is no movement of the system.

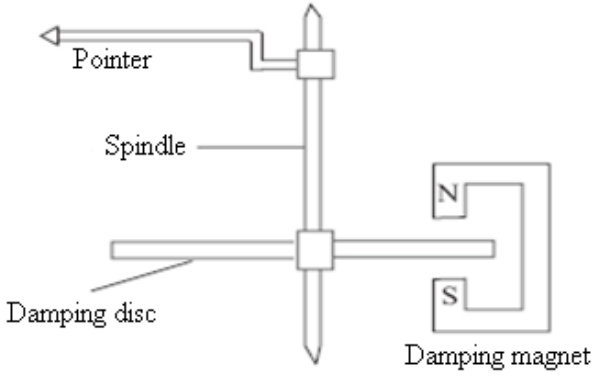

Figure 4.6: Eddy Current Damping

In Fig. 6 a thin disc of conducting, but non-magnetic material-usually copper or aluminium is mounted on the spindle which carries the pointer of the instrument. When the spindle rotates, the edge of the disc cuts through the lines of force in the gap of a permanent magnet, and eddy currents, with consequent damping, are produced.

Moving – Coil Instruments

Accurate measurement of current and potential difference (voltage) is needed in all branches of electricity and their applications, for example in television, radio telecommunications, dynamos and motors.

The most widely used commercial meter is the moving coil type. Basically, it consists of

1) A rectangular coil with many turns
2) A powerful radial magnetic field between curved pole pieces N and S and a soft iron cylinder
3) Springs to control the angle of rotation of the coil
4) A uniform (linear) scale for measuring the current.

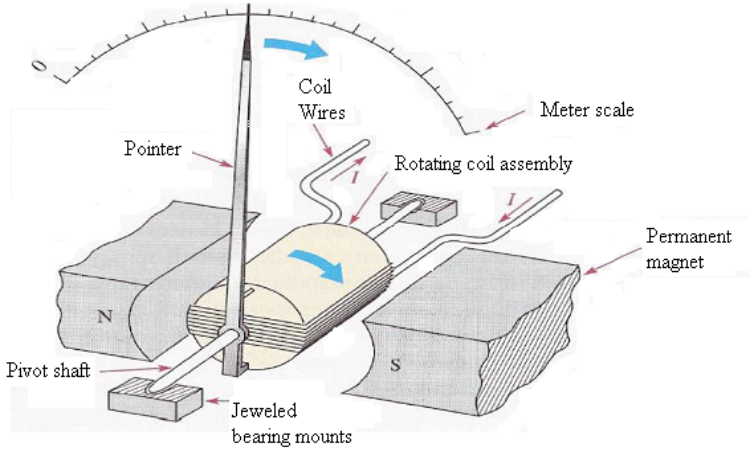

Figure 7: Moving Coil Instrument

The moving coil instrument operates through the interaction of two magnetic fields; the permanent magnet field and the field due to the current flowing through current carrying conductors. The moving coil instrument is commonly used in voltmeters, ammeters and ohmmeters. It responds only to direct current. It is used in rectifier- type instruments to measure alternating current and voltage. There are two types of moving coil instruments

1) Dynamometer type
2) Permanent magnet type

Electrodynamic (Dynamometer) Instruments

These instruments are the modified form of Permanent Magnet Moving Coil (PMMC) instrument in which the operating field is produced, not by a permanent magnet but by a two air-cored fixed coils placed on either side of the moving coil as seen in fig. 4.8. Electrodynamometer meter movements use stationary coil and moving coil to develop interacting magnetic fields, i.e., the electrodynamometer uses two electromagnetic fields in its operation. One field is created by the current flowing through a pair of series-connected stationary coils. The other field is caused by current flowing through a movable coil that is attached to the pivot shaft. If the current in the coils are in the correct directions, the pointer rotates clockwise. The rotational torque on the movable coil is caused by the opposing magnetic forces of the three coils. They respond to alternating current because the a.c. reverses direction simultaneously in all three coils and also can operate on direct current and are used in wattmeters. Electrodynamometer meters have low sensitivity and high accuracy.

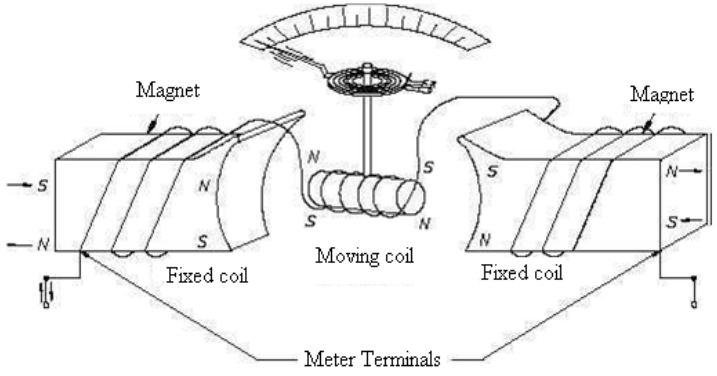

Figure 8: Dynamometer Instruments

The operating principle of electrodynamic instruments is the interaction between the currents in the moving coil, mounted on a shaft, and the fixed coils, ie., the deflecting torque is produced by the reaction between the magnetic field set up by the current in the moving coil and the magnetic field set up by current in the fixed coils. When the two coils are energized, their magnetic fields will interact as a result, mechanical force exist between the coils and the resulting torque will tend to rotate the moving coil and cause the pointer attached to it to move over the scale. Since there is no iron, the field strength is proportional to the current in the fixed coil and therefore, the deflecting torque is proportional to the product of the currents in the fixed coil and the moving coil.

Deflecting Torque

The force of attraction or repulsion between the fixed and moving coils is directly proportional to the product of ampere turns (ampere turn of a coil = product of its no. of turns and current flowing through them) of fixed coils and the moving coils i.e.

Deflecting torque, $Td \propto N_F I_F \propto N_M I_M$.

Since N_F and N_M are constant :

$Td = I_F \propto I_M$

The scale of these instruments is not uniform, being crowded at the beginning and open at the upper end of the scale. The obvious disadvantage of such a scale is that the divisions near the start of the scale are small and cannot be read accurately.

Control System

The controlling torque is produced by two control springs, which also act as leads to the moving coil.

Damping System

This system provides air – damping. **Advantages of**

Dynamometer Instruments

- These instruments can be used for both d.c and a.c measurements.
- Since the coil is generally air cored, they are free from eddy current and hysteresis losses.
- They can be used for power measurements.

Disadvantages of Dynamometer Instruments

- They have low sensitivity
- Such instruments are more expensive than the other types
- As the deflecting torque varies with the square of the current, the scale is not uniform.

The dynamometer instrument may be applied or used as an ammeter or as a voltmeter but is generally used as a wattmeter. They are suitable for d.c as well as a.c.