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Aims and Scope

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Recent Trends in Power Converters for Wind Energy Conversion System with Grid Integration Impact

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ABSTRACT

This paper discusses trends of the most emerging renewable energy source, wind energy. The current status of wind energy and Wind Energy Conversion System (WECS) with different wind turbine generators with their technical features and converter topologies are presented in this paper. Grid integration of variable wind power is confronted with many challenges. These challenges and issues also summarized in this paper. The main focus of this paper is two main electrical aspects: 1) Different converter topologies for Permanent Magnetic Synchronous Generator (PMSG), emphasizing on advantages, and control techniques, 2) Issues and impact of wind energy integration into the grid.

Keywords: BDFIG (Brushless Doubly Fed Induction Generator), BDFRG (Brushless Doubly Fed Reluctance Generator), PECs (Power Electronic Converters), PMSG (Permanent Magnetic Synchronous Generator), Grid impact, Wind energy.

I. INTRODUCTION

A. Status for Wind Power

Renewable Energy Technologies are being welcomed in many countries, because of their minor or nonimpact on the environment. They have been an alternative to meet society demands regarding to quality and safety on electricity supply. Wind energy is one of the most emerging renewable energy. It has been the flag bearer for the Indian Renewable Energy (RE) industry for quite some time now. In the last three years, 60% of total RE investment has been done in wind energy.

The development of wind power in India began in the 1980‘s and it has progressed steadily in last two years. Wind energy demonstrates the potential to contribute significantly in attending the requirements on the costs of production, supply security and environment sustainability [1]. The progress of the overall wind energy has been encouraging by governments to the wind farm growth. In Brazil, BNDES (National Development Bank) recently approved funding for nine wind farms with total installed capacity of 281.5 Mega Watt (MW) [2]. The increasing reliability and performances of wind energy have made wind power a favoured choice for capacity addition in India. Currently, India has the fifth largest wind power capacity in the world with a cumulative installed capacity of 14158 MW [3]-[4].

In India the total potential for wind power was first estimated by the Centre for Wind energy Technology(C-WET) at 45 GW. This potential could be as high as 100GW with large turbines. This figure is given by The World Institute for Sustainable Energy. Energy Alternative India (EAI) has done an independent research and estimates the total onshore potential for wind energy could be as high as 120 GW. Everything is well with wind industry, but if one factors in dramatic increase in electricity demand that India will face over the next decade, it is seen that wind power power‘s contribution will remain negligible. The reason is that wind power generates only 2% of the country‘s power while it accounts for about 8% of India‘s total power capacity. Table 1 shows the possib le contributions by wind energy to the total electricity produced in India by 2020.

Table-I: Summary of Wind Energy Outlook Scenario for 2020 – India [5]

Growth Scenario	Cumulative Wind Powe r Capacity (MW)	Electricity Output (GWh)	Share of Elec. Demand (per cent)	Output
Reference	20332	40665	2.6-2.8	610
Moderate	63230	126459	8.1-8.7	8247
Advance	134828	269656	17.3-18.6	9438

Attitude challenges, transmission challenges, regulatory and structural challenges, efficiency challenges efficiency challenges are some issues which are facing by Indian wind power industry [5].

B. Wind Energy on Distributed Generator

Wind energy is the most promising and clean energy. The increasing price-competitiveness of wind energy against other fossil fuel energy sources such as coal and natural gas is another positive indication on wind energy. Power generation by wind turbines has been widely used in composition of micro-networks [2], usually associated with photovoltaic panels [6]-[8], forming hybrid system that is more robust than single-source system [9].

In the present scenario Power Electronics (PECs), being the technology of efficiently converting electric power plays an important role in wind power. It gives the ease for integrating the variable speed wind system units to achieve high efficiency and performance when connected to the grid.

This paper deals with the different converter topologies in use with PMSG and grid impact of the converter fed Variable Speed Wind Turbine (VSWT).

The structure of this paper is as follows: the component of wind power conversion system, emphasizing the generator and converter topologies are firstly discussed in section II, followed by the impact and issues associated with grid integration of variable power into power grid in section III. Finally conclusions are drawn in section IV and references in section V.

II. WIND POWER CONVERSION SYSTEM

The main component of wind turbine system is shown in Fig 1. Wind turbines capture power from the aerodynamically designed blades and convert it into rotating mechanical power. As the radius of blade increases, the rotation speed will be decreases. During higher wind speed, it is necessary to control the converted mechanical power. It may be done by stall control, active control, or pitch control whose power curves are shown in Fig 2 [10]-[11]. The common way to convert the low speed (high torque) of turbine to the high speed (low torque) of generator is using gearbox and generator with standard speed. Then this power is fed to the grid through power electronic interface and for grid connection transformer is used.

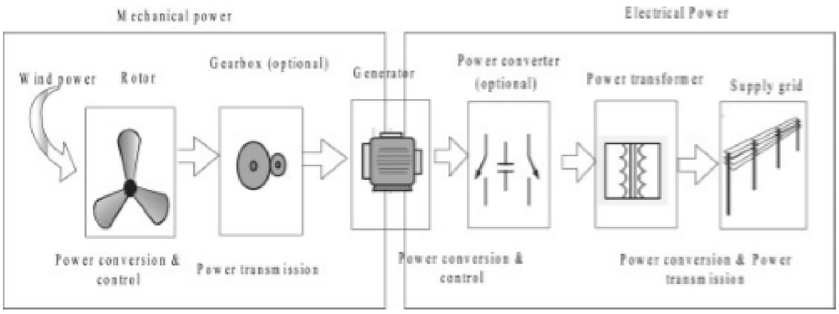


Fig.1 Main component of a wind turbine system [12]

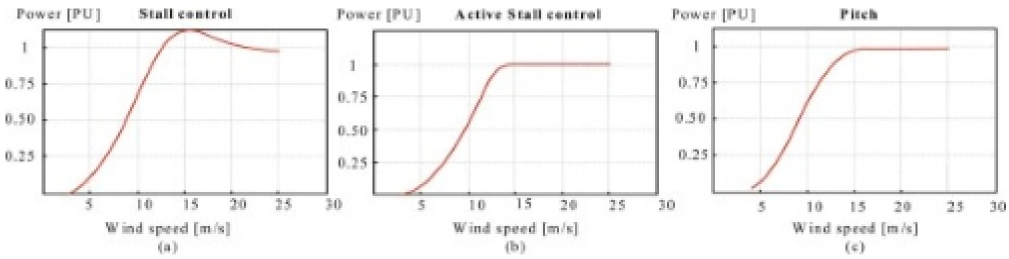


Fig.2 Powe r characteristics of fixed-speed wind turbines [11].
(a) Stall control. (b) Active stall control. (c) Pitch control

A. Wind Generator

Wind Turbine Generators (WTGs) may be classified into two categories: fixed speed and variable speed. Variable speed WTGs, based on rating of PECs, again classified as wind generator with Partial Scale Frequency Converter (PSFC) and Full Scale Frequency Converter (FSFC) [13].

1) Fixed Speed Wind Turbine (FSWT) Generator:

This configuration corresponds to the Danish concept that was very popular in 80's. FSWT including SCIG (Squirrel Cage Induction Generator) directly connected to the grid via a transformer as shown in Fig 3.

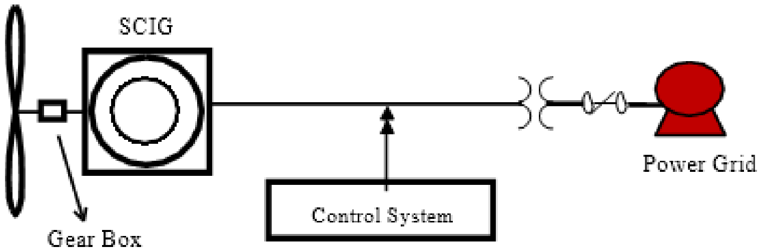


Fig.3 Self-excited induction generator based fixed speed wind turbine [14]

A synchronous condenser or capacitor bank is used for reactive power support, which can be supplied by parallel capacitor bank at the machine terminal. If the reactive power support is not adequate the SEIG may suffer from large scale wind farm penetration.

2) Variable Speed Wind Turbine (VSWT) Generator with PSFC:

This configuration is known as Doubly-Fed Induction Generator (DFIG) shown in Fig 4. The stator of the induction generator is directly connected to the network and the rotor is mediated by the electronic converter, the reason why they are inserted in the system with partially rated power electronics [15]. The power rating of this PSFC defines the speed range (typically ±30% around synchronous speed).

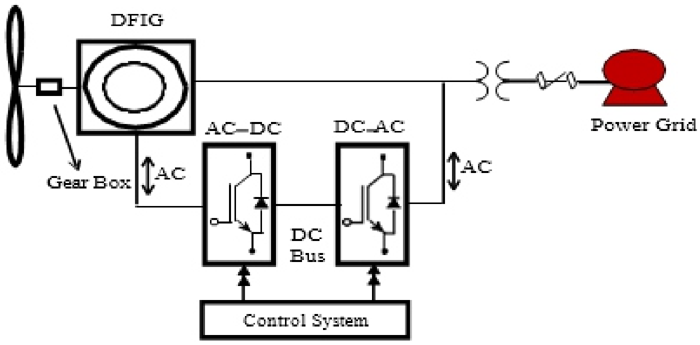


Fig.4 DFIG based variable speed wind turbine [14]

Due to inherent characteristics of DFIG, Brushless Doubly Fed Induction Generator (BDFIG) and Brushless Doubly Fed Reluctance Generator (BDFRG) are two new concept of VSWT with PSFC in the current research area. As shown in Fig 5 BDFIG consist of two cascade induction machine; one is used for generation and other is used for the control. The advantages of BDFIG are reported in [16], [17]-[18] including its capability with low operation speed. In BDFRG, there is a reluctance rotor, which is usually an iron rotor without copper winding as shown in Fig.6. Due to its reluctance rotor it offers higher reliability including its ―fail- safe‖ operating mode [19]-[22].

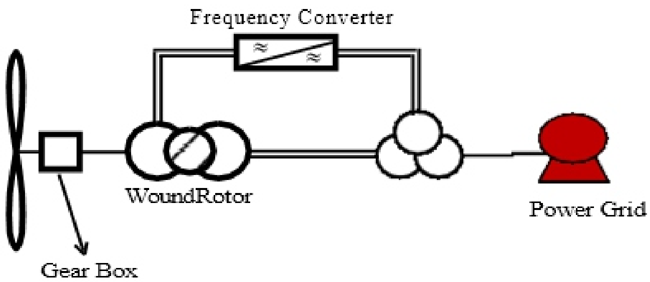


Fig.5 The conceptual diagram ob BDFIG [23]

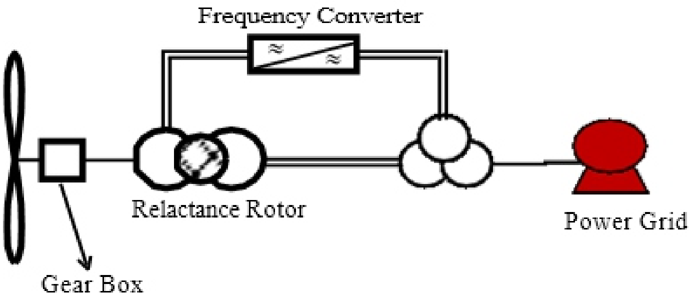
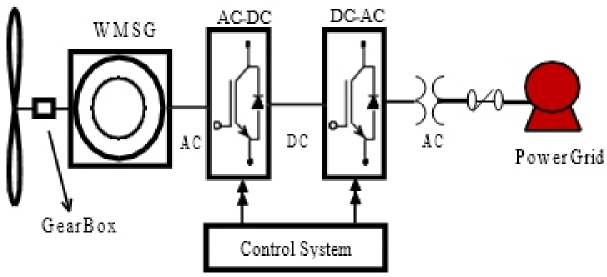


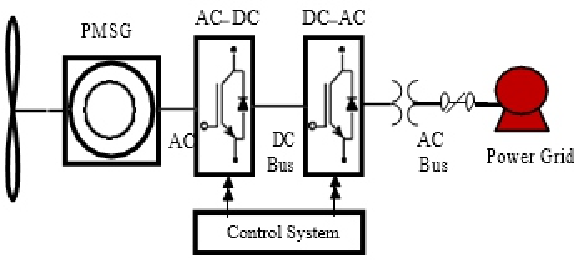
Fig.6 The conceptual diagram of BDFRG [23]

3) Variable Speed Wind Turbine (VSWT) generator with FSFC:

The variable speed wind turbine are equipped with a Self Excited Induction Generator (SEIG), Doubly Fed Induction Generator (DFIG), Wound Rotor Synchronous Generator (WRSG), and Permanent Magnetic Synchronous Generator (PMSG) and connected to the grid or load through FSFC. Different types of VSWTs are shown in Fig 7. The reactive power compensation and smooth grid connection for the entire speed range is done by FSFC.



(a) WRSG



(b) PMSG or Muti-pole synchronous generator

Fig.7 Different types of VSWT [14]

Some VSWTs are gearless as given in Fig 7. The interest in direct-drive VSWT is increases day by day. The reason is its superior performance and fault ride through-capability. PMSG has received much attention in wind energy application because it can be designs with higher number of poles and thus a low speed direct drive (gearless) operation is possible [24]-[25].

Among the six concepts, the two concepts BDFIG and BDFRG are in the recent research area. Rest four concepts exist in the current market. Table II shows the advantages and disadvantages of all the six concepts.

Table. II: The advantages and disadvantages of the six WTG concepts [23]

Generator Concept (Type)	Advantages	Disadvantages
SCIG	Easier to design, construct and control, Robust operation, Low cost.	Low energy yield, No active/ reactive power controllability, High mechanical stress and losses on gear.
PMSG	Highest energy yield, Higher active/reactive power controllability, Absence of slip-ring, Low mechanical stress, No copper losses on rotor.	High cost of PM material, Demagnetisation of PM, Complex construction process, Higher cost on PEC, Higher losses on PEC, Large size.
WRSG	High energy yield, Higher active /reactive power controllability, Absence of slip-ring, Low mechanical stress.	Higher cost of Power winding, Higher cost on PEC, Higher losses on PEC, Large size.
DFIG	High energy yield, High active/ reactive power controllability, Lower cost on PEC, Lower losses by PEC, Less mechanical stress, Compact size.	Existence of slip-ring, High losses on Gear.
BDFIG	Higher energy yield, High active/ reactive power controllability, Lower cost on PEC, Lower losses by PEC, Absence of slip-ring, Less mechanical stress, Compact size.	Early technical stage, Complex controllability, design and assembly, High losses on Gear.
BDFRG	Higher energy yield, High active/ reactive power controllability, Lower cost on PEC, Lower losses by PEC, Absence of slip-ring, No copper losses on rotor, Less mechanical stress, Easier construction.	Early technical stage, Complex controllability and rotor design, High losses on gear, Large size than DFIG.

B. Power Electronic Converters

Power electronics technology has changed rapidly during the last three decades. PECs, depending on the topology and the application may allow both direction of power flow. Basically there are two different types of PECs: grid commutated and self commutated. The Grid commutated converters are mainly thyristors converters, which consumes inductive reactive power and unable to control the reactive power. Self commutated converter system usually adopts Pulse Width Modulation (PWM) method. This type of converter may transfer both active power and reactive power [16], [26].

Various possible technical solutions of WECSs are related to PECs. They can improve dynamic and steady state performances help to control the WTGs and decouple the generator from the electrical grid [27]. Following the most cited topologies in literature will be discussed.

1) Diode Rectifier:

It is used as AC/DC converter. There is a DC link element, which can be a capacitor in Voltage Source Converter (VSC) or an inductor in a Current Source Converter (CSC) [28]- [39]. The applicability of this topology occurs because there is no need of external excitation. It provides many options for secondary stage conversion and its control. For example chopper is used as intermediate DC/DC stage. These topologies are observed in Fig 8.

2) Back-to-back two level converter:

According to [40], it is the most popular technology. Fig 9 shows the basic topology using a six switch converter. This converter uses a PWM modulation on both sides. In [41] the control of generator side is done by a PI controller.

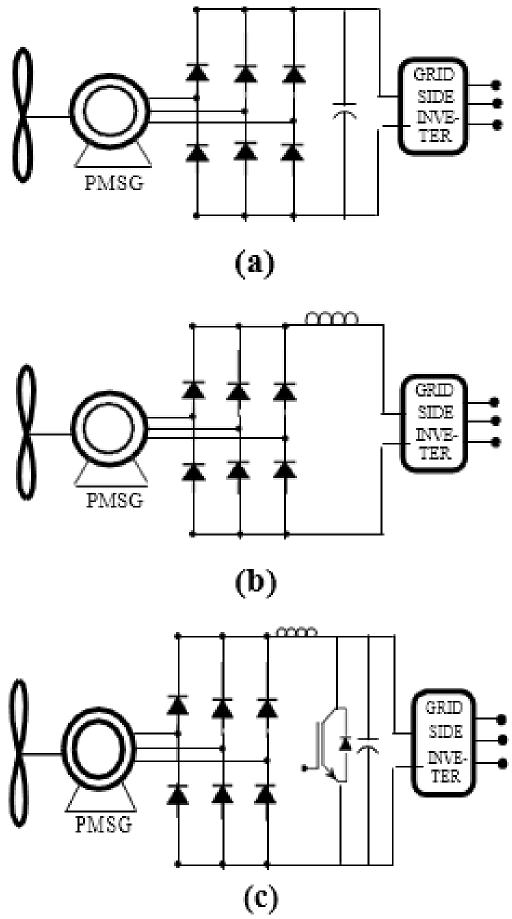


Fig.8 Conversion system based on diode rectifier,
(a) Voltage output, (b) current output, (c) DC/DC stage boost [47]

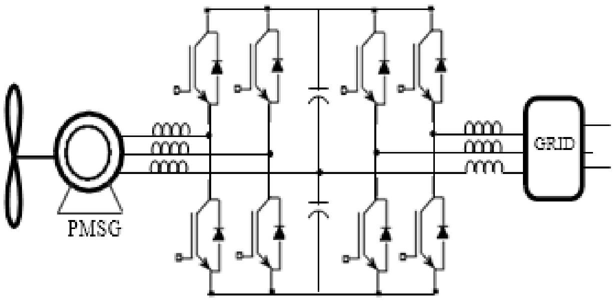


Fig.9 Conversion system based on back-to-back two-level converter with reduced- part number [47]

3) Multilevel converters:

These converters are a good choice in application where high voltage rating is necessary [42], due to voltage level of the converters. In this topology the control technique is PWM. This topology is given in Fig 10. There have been various designs for multilevel converters including Neutral Point clamped (NPC), Cascade Half- Bridge (CHB), Fly Capacitor (FC) [43]-[46].

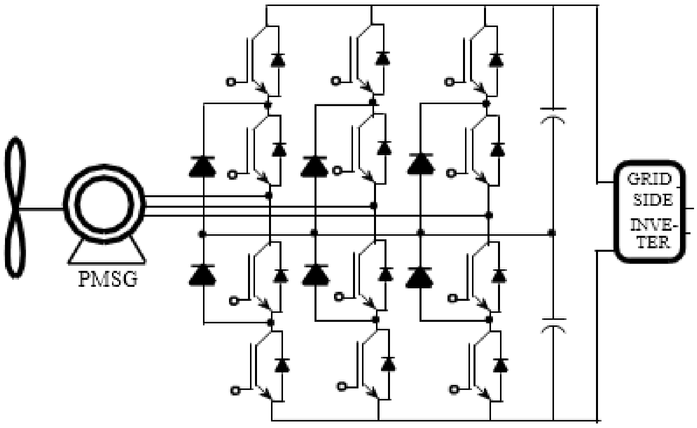


Fig. 10 Conversion system based on multilevel converters [47]

4) Semi-controlled rectifier converter:

The topology given in Fig 11 used only two semiconductors in the rectifier stage operation. In [29] it is given that constant frequency PWM controllers tend to increase the current Third Harmonic Distortion (THD) due to discontinuities. So rectifier control system uses the principle of hysteresis control.

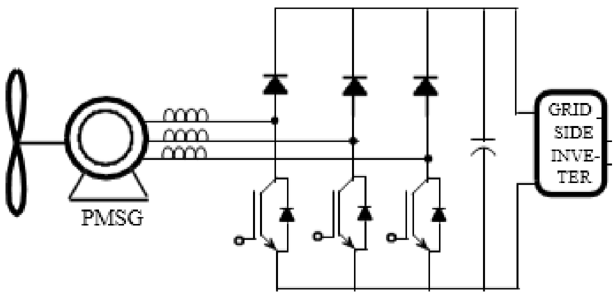


Fig.11 Conversion system based on semi-controlled rectifie r-boost converter [47]

5) Matrix converter:

The matrix converter given in Fig 12 is an AC/AC converter in which DC link stage is absent. It provides a smaller converter promoting more reliability in comparisons to others. Due to its complex control it has not been accepted in industrial applications [48]-[49].

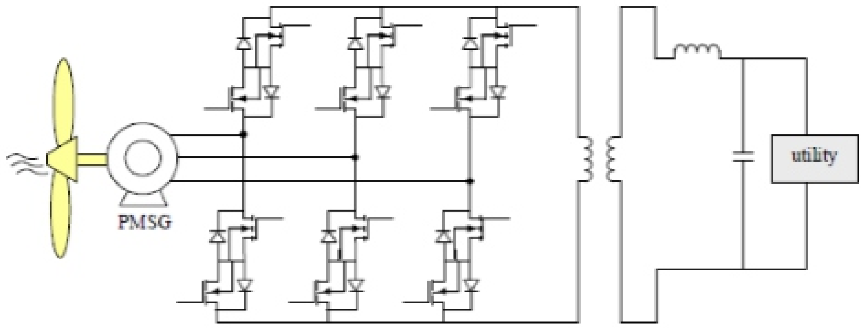


Fig.12 conversion system based on matrix converter [47]

6) Three single-phase converter:

This topology is illustrated in Fig 13. It operates on continuous conduction mode. In this case three single-phase converters are used on rectifier stage [50].

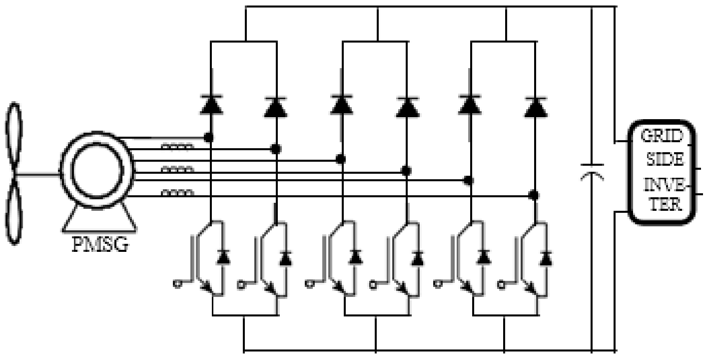


Fig.13 conversion system based on three single-phase converters [47]

Table III illustrate the advantages and disadvantages of all the converters which are given in this literature.

TABLE III : The advantages and disadvantages of different converter topologies

Converters	Advantages	Disadvantages
Diode Rectifier	Simple, low cost, Less harmonic distortion, low losses.	Low efficiency
Back-to-back two level converter	Provide active and reactive control, High power factor in the generator side, High efficiency	Short life, High Switching losses and frequency harmonics
Multilevel converter	Higher voltage and power capability, Low switching losses	Voltage unbalanced on DC link, Complex control
Semi- controlled rectifier converter	Circuit command is simple, Fewer power stage, High efficiency, Low losses	Higher harmonic content
Matrix converter	Provide smaller controller, Control is performed only on one converter, High efficiency, Low switching loss and harmonic emission	Output voltage is limited, Higher conducting losses, Expensive, Complex Control
Three single- phase converter	Independence on operating between the converters, Rectifier stage operation is done by only two semiconductors in each phase.	It is used only for continuous conduction mode.

III. ISSUES AND IMPACT OF WIND ENERGY INTEGRATION INTO THE GRID

Due to intermittent nature of wind, the integration of wind generation into the grid can introduce many technical challenges and issues. The challenges and issues associated with the wind generation and integration to the grid are discussed below.

A. System Inertia and Frequency Regulation

With a high level of penetration, the intermittency of wind generation in system impacts the system dynamic performances. [51]. In conventional power plants, this problem is taken care of by the synchronous generator directly connected to the grid. However, wind farm power output is required to be regulated at a desired dispatch-ability level if the penetration level is high [52].

B. Intermittency of Wind

If the large numbers of wind turbines are connected to the electrical grid, the rapid variability of wind power on short time scales can cause the grid frequency to deviate significantly from its nominal value [53]-[54]. Traditionally, the grid frequency is regulated by the conventional power plant with synchronous generator. The differing dynamic performance and inertial response of VSWTs compared to conventional synchronous generators has caused concern to power system engineers and operators.

C. Fault Ride-Through Capability of Wind Turbines

The electrical system can be said to be stable when the synchronous machines connected to it operate in synchronism and there is a balance between the demand and production of both active and reactive power. The factors affecting fault ride-through that can be said to be attributable to the electrical system are as follows [55];

- Shape of the voltage dip and absolute level of the voltage dip, Fault type and location,
- Fault clearance time,
- Grid strength, Grid architecture ,
- Active and reactive power conditions prior to the fault
- Active and reactive power requirements after fault clearance, Load characteristics.

With the increased wind penetration, utility operators have to make sure that power system operates properly without compromising power quality and stability. Many power systems have made grid codes to require that the wind turbines be connected in a system during a power system fault, in order to support the system recovery from a fault. This becomes more significant as wind power penetration level increases. Among the grid requirement, the fault ride-through is regarded as the main challenge to the wind turbine manufacturer [55]-[56].

D. Ramping Due to Wind Speed Variation

Due to wind speed variation, the fast power ramp is another issue on wind energy integration [57]. In many countries, by adjusting the power output of fast-ramping gas turbines, the grid frequency is typically regulated but it can be expensive to operate. Batteries and flywheels are technically good to rapidly generating or absorbing power. The drawback of batteries and flywheels is that, the commercially available units are too expensive on the scale needed for the penetration of wind power expected in the next decades. The best way is to use hydroelectric power and specially pumped hydro storage. It is relatively inexpensive. However, little new pumped hydro storage is being developed [58].

E. Congestion on the Power Transmission Grids

The inability of transmission line to deliver power under some loading condition is called transmission congestion. The generation of power from RE is increases day by day. So electric power networks are grown up rapidly but power transmission lines are not expanded as the same pace. The problem of congestion is a new challenge in the field of electric transmission network [59]-[60].

F. Power-Quality Requirements for Grid-Connected Wind Turbines

Large-scale integration of wind turbines may have significant impacts on the power quality and power system operation. Conventionally, wind turbines are not required to participate in frequency and voltage control. However, in recent years, attention has been increased on wind farm performance in power systems [61]-[64].

Recent studies show that power quality impact of wind turbine improved especially concerning flicker problem. However, it has been reported in [56] that modern forced- commutated inverters which used in some non-synchronous sources still inject not only harmonics but also inter-harmonics in the system. This issue might get worse for large scale wind integration into the power grid.

IV. CONCLUSION

This paper has reviewed the different converter topologies for PMSG and the grid integration impacts. Various wind turbines with different generators are described. Two recent concepts BDFIG and BDFRG are also discussed. However there are currently few researches being undertaken. The technological advances on material and converters have allowed the use of PMSG on high power applications.

PECs are the important key in generator grid interface. Concerning the front-end stage from the PMSG view-point, multilevel converters seems very attractive with the increasing wind turbine size and its characteristic with the grid. For low power, discontinuous mode, single or three switch high power factor rectifiers seems to be a good solution.

With the increasing level of wind turbine penetration in current power systems, grid connection issues have posed a number of new challenges to WECs design. In future, the percentage of wind energy on many grids is likely to be a significant part; therefore it is necessary to advancement in WECs as key grid company.

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Optimum Sizing of Photovoltaic Diesel-Generator Hybrid Power System

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ABSTRACT

This paper presents the methods to minimize the cost of PV system according to reduction of PV array area and storage battery. A new method has been used to calculate the minimum PV array area and minimum number of storage days of the battery. A program has been developed by using MATLAB software, for sizing of Photovoltaic Diesel-Generator Hybrid Power System. This program is used to size hybrid system which consist of PV system, storage system and diesel generator. Characteristic curves also have been developed for PV system and total battery capacity. Thus, this proposed method can be used to size any system.

Keywords: Photovoltaic system, Diesel generator.

I. INTRODUCTION

Photovoltaic (PV) system installation has played an important role in the solar industry because PV systems are clean, environment friendly and secure energy sources. However the drawback of PV systems is their high capital cost compared to that of conventional energy source. Therefore, many research studies have focused on the optimization of PV system, such as Hybrid PV/Diesel generator system. Hybrid Photovoltaic Systems (PV-hybrid) use photovoltaic energy combined with other sources of energy, like wind or Diesel. If these systems are optimally designed, they can be more cost effective and reliable than PV-only systems. Some of the methods for sizing of Hybrid Systems are (i) HOGA (Hybrid Optimization by Genetic Algorithms) based [1] (ii) FORTAN language based [2] (iii) SDM and SAR based [3].

Rodolfo Dufo-López, Josė L. Bernal-Agustĭn, et al in [1] proposed a method to size Hybrid system using HOGA program. P. Arun, Rangan Banerjee, Santanu Bandyopadhyay [4] used Monte Carlo simulation approach to size a hybrid system. Said H. EL-HEFNAWI [2] proposed a method using FORTAN language.

In this paper sizing a method for Photovoltaic Diesel-Generator Hybrid system is given. PV array area and minimum number of storage days of battery has been calculated using efficient formulae. Characteristic curves using MATLAB software has been developed.

II. CONVENTIONAL STAND ALONE SYSTEM SIZING TECHNIQUES

The first step in stand-alone system sizing is to select the battery capacity for battery storage to cover exceptionally long periods without sunshine or at night. The second step is to decide the acceptable depth of discharge (DOD) for the system battery under normal seasonal fluctuations in solar energy input. Current and voltage output are sized separately. The voltage output should be large enough to allow the battery to be charged efficiently throughout the year. In selecting the system voltage, the effect of temperature must be considered. The output current is chosen to ensure that the battery does not charge the selected DOD during the worst case seasonal effects or days without sun. The system sizing characteristic depends on the conditions of the site and there is no exact formula for that purpose, but there are empirical equations for system sizing in different applications. In a solar PV powered rural health center in India, the size of a stand-alone PV system is obtained from the following relationship:

$$P_V = \frac{\{E_L + (E_L + \frac{D}{C_R} * BE) * 100\}}{X}$$

Where

P_V : The array size in peak watts

E_L: The daily energy requirement in Wh / day

D: The required number of storage days

C_R: The charge recovery of the battery days

B_E: The watt-hour efficiency of the battery

X: the annual average equivalent peak hours/day (sunshine period)

For the required battery storage of D number of days, the battery capacity is obtained as follow:

$$C_t = \frac{(E_L * D)}{(V_S * D)}$$

Where

V_S: The system voltage

C_D: Maximum permissible depth of discharge

In the previous methods for stand-alone system sizing, the number of storage days has not determine a direct relation, since it was dependent on the total number of days without sun during the year, which depend on the nonregular characteristics of weather sites. Also, the maximum permissible DOD does not have a constant value due to variation in weather parameters from one year to another. The previous two problems are solved and governed in a fixed formula in a hybrid system.

III. HYBRID SYSTEM SIZING

A. Diesel Generator Sizing

The main concern for the diesel-generator sizing and optimized operation are: the diesel shall not be lightly loaded; the diesel runs for sufficient period of time to reach operating temperature; and the excessive operation during the final charge period be avoided. The optimum diesel-generator operating range is 70-89% from the rated power. The diesel generator chosen was a KOBOTA, 3kw, single phase generator, with manual and automatic starting and self-regulation using a governor to give the engine an accurate fuel quantity at different load requirements. The governor acts to keep the engine speed (generator frequency) approximately constant at any load level.

B. PV Stand-Alone Sizing in Hybrid System

To size the PV array and the battery capacity, the average load energy EL and the ampere- hour required per day (Ahr) should be estimated from the load profile. The ampere-hour required per day is:

$$Ah_r = {}^{E_L}/_{V_s}$$

Where

V_s is the system voltage

Ahr is used to calculate the required current from the PV array

C. Battery Capacity Determination

The battery capacity C t is given in equation (3.2). Using this relationship, the ideal battery capacity can be calculated at 100% charge –discharge efficiency, bit the charge-discharge losses are approximately 25% of the total capacity. The charge losses refer to the PV side, but the discharge losses refer to the battery side. The watt-hour efficiency (WHE) for a lead- acid battery has a value of 75% and is defined as:

$$BCT = \frac{Ah_r * D}{C_D * \sqrt{WHE * M}}$$

The discharge efficient should be calculated to their part of energy only which is Ahr. By including the discharge efficiency and the maximum permissible state of charge SOC (M), in the battery capacity determination, the total battery capacity (BCT) is:

$$C_D = \frac{(C_t - Ah_r)}{C_t}$$

The minimum number of storage days is:

$$D = CD * (D+1)$$

By determining the required maximum permissible DOD, the minimum number of storage days can be calculated.

D. Current Determination

The average PV system current is:

$$I_a = \frac{An_r}{(number\ of\ sunshine\ hours\ per\ day)}$$

Considering charging efficiency, this current should be:

$$I_{a1} = \frac{I_a}{\sqrt{WHE}}$$

By including the low level insolation and highly dust accumulation periods, the average current should be increased by a 5% ratio. Then the PV output current is:

PVC = Ia1 * 1.05

E. Voltage Determination

Voltage determination to charge a 12 V battery is 13.V. The required system voltage should be large enough to charge the batteries, so:

Vs = (number of batteries in series)*13.6+ voltage drop across blocking diode

E. PV Module Configuration

The number of modules in series = Integer part of (System voltage/module voltage) + 1 The number of parallel strings = $\frac{\text{Photovoltaic current}}{\text{String current}}$

IV. ALGORITHM FOR SIZING OF HYBRID SYSTEM

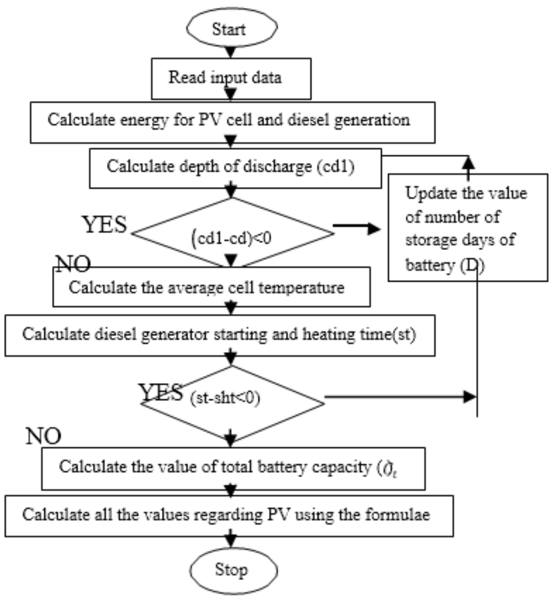

Fig. 1. Flow Chart

V. CASE STUDY

Data are collected at an isolated farm in the Egyptian Eastern Desert, site latitude 27' and meridian 33 E.G. The average irradiation is 6.88Wh/m2/d and the sunshine period is 9 h/d for 350 d/year. The system voltage is 24 V. The load profile (Fig 2) can be deduced from the load data by calculating the distribution of load during day as follows:

22 - 6	L= 99.6 W	(8 h)
6 - 7	L= 74.6 W	(1 h)
7 - 10	L= 82.1 W	(3 h)
10- 15	L= 2461.8 W	(5 h)
15-18	L= 82.1 W	(3 h)
18-22	L= 282.6 W	(4 h)

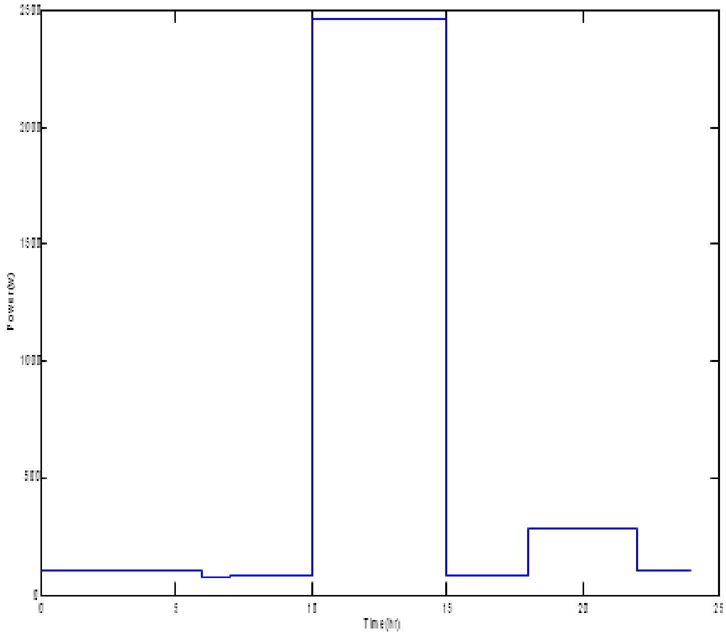

Fig. 2. The load profile

It can be seen from the load profile that the overload period lies between 10-15, therefore, the diesel generator should be used in this period. To optimize the hybrid system design, the load profile should be divided into two sections during the overload period: (1) PV stand- alone load which has a value of 74.6 W; and (2) the diesel-generator load which has a value of 2387.2 W. Then, the daily energy required from the stand-alone PV system section (PV array and battery) is:

$$EL= 99.6*8 + 74.6*6 + 82.1*6 + 282.6*4 = 2867.4 \text{ W}$$

VI. MODULE PARAMETER CORRECTION DUE TO SITE PARAMETERS

The available modules for our system have the following data: Un =9.6 V, Pn=23.3 W, dimension 46*56 cm2, number of cells = 20 in series, but have internal blocking diodes. Generally, the module data is given at standard test condition (STC): Irradiance 1000 Wh/m2, with the references solar spectral irradiance distribution, cell temperature 250C and the tests are carried in laboratory. The previous parameters will be changed according to site parameters. The average irradiance is 6.88/9 kw/m2 =760 w/m2. The expected theoretical modules characteristics for site parameters are:

$$P_n = V_n * I_n$$

$$I_n = \frac{23.3}{9.6} = 2.4167\ A$$

$$I_M = I_n * (\text{average on site irradiance/STC irradiance})$$

$$= 2.4167 * \frac{760}{100} = 1.8367\ A$$

$$V_M = V_n - (t\Delta 3mV^* \text{ no. of module cells})$$

$$= \quad -9.6-[(35-25) * (3*10^{-3})*10] = 9\ V$$

$$P_M = V_M * I_M = 16.53\ W$$

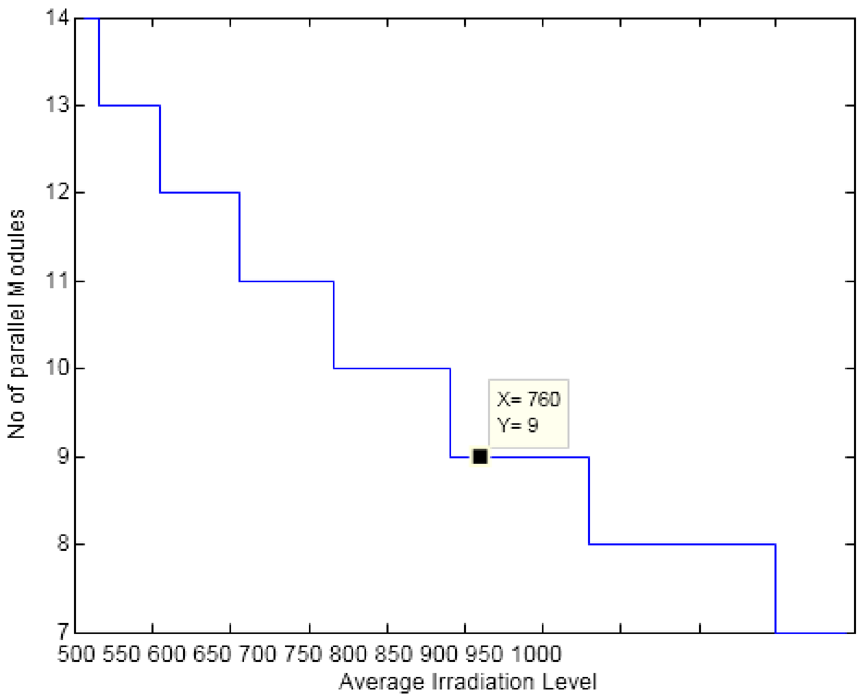

FIG 2: Variation of parallel modules with change in average irradiation level.

By using the previous initial values, the results obtained from the system sizing program are:

CD1 = 0.7509	D = 3.0150
BCT = 553.9008	ST = 6.2354 min
NOSM = 4 module	NOPS = 9 string
PVC = 16.0951	RSV = 27.9000
VM = 9V	PM = 16.6013
OMC = 1.8446	NOSB = 2
SC = 4.9781	SP = 597.6450

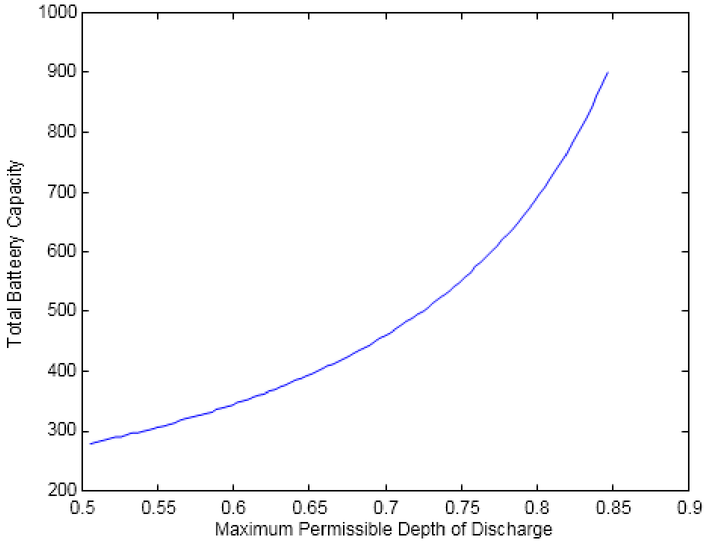

Fig. 3. Variation of total battery capacity with change in depth of discharge

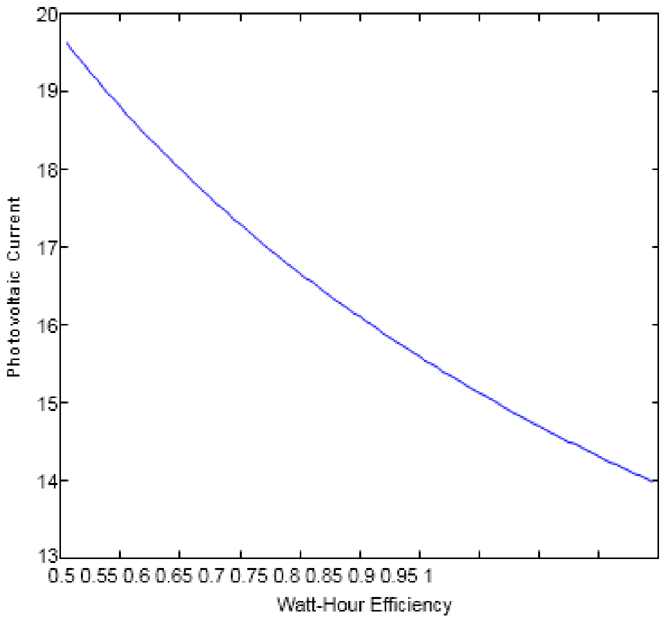

Fig. 4. Variation of Photovoltaic current with change in Watt-Hour Efficiency.

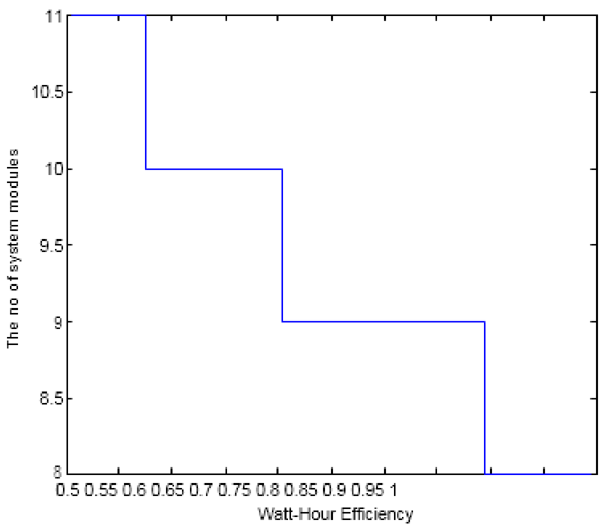

Fig. 5. Variation of the no. of system modules with Watt-Hour Efficiency

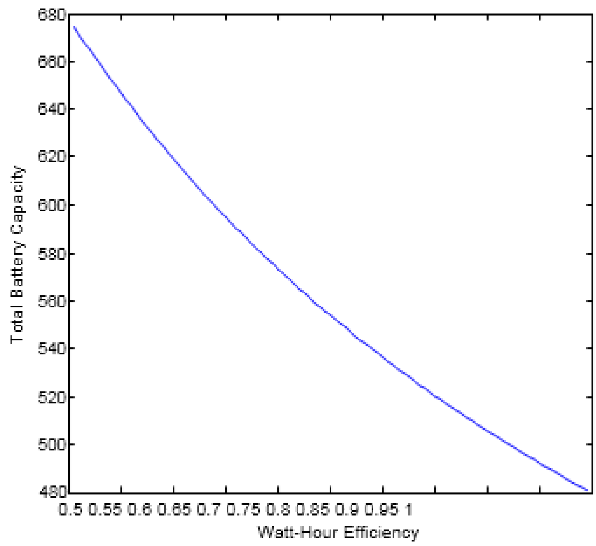

Fig. 6. Variation of total battery capacity with change in Watt-Hour Efficiency

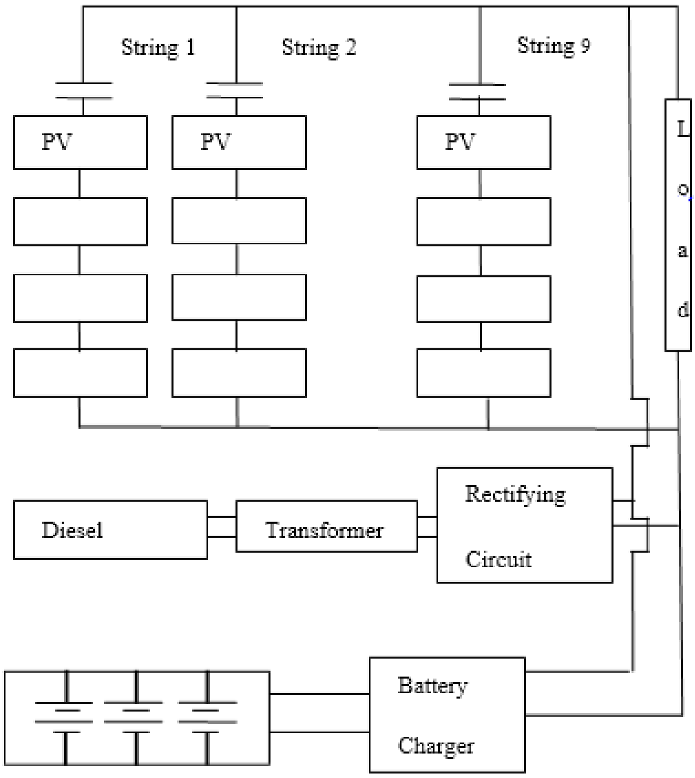

Fig. 7. The System Profile

VII. CONCLUSION

The importance of renewable energy and why we use renewable energy is discussed. The development of solar energy utilization for power generation is also discussed.

The maximum number of storage days has been determined and the maximum permissible depth of discharge is limited. The sizing program developed can be used to size any PV diesel-generator hybrid power system. The available pre-operating period for a diesel- generator is determined according to the engine type selected. The sized hybrid system is reliable and can absorb any load disturbances. The hybrid system is more economic than the stand-alone system, because of the minimization of array size and battery capacity required.

A case study has been done and results are presented for a given load at an isolated farm in the Egyptian desert, site latitude 270 and meridian 33 E.G.

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Levy's Power Conservation Method (LPCM) –An Innovative Approach for Efficient Power Saving and Reduced Electromagnetic Radiation Strategies

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ABSTRACT

This paper presents a novel method of power saving and reduced electromagnetic radiation from antennas used in wireless mobile communications. Now-a-days seeing a person without mobile phone is very difficult. Even though people are worried about the electromagnetic radiation biological effects but using the mobile phone is in evitable. This paper a new method is proposed which can reduce the power consumed and electromagnetic energy radiated from the mobile antennas with the help of new design of mobile phones along with global positioning system. This is called Levy's power conservation method.(LPCM).

Keywords: Electromagnetic radiation effects; Global positioning systems; Levy' power conservation method (LPCM); Power conservation techniques.

1. INTRODUCTION

MOBILE phones are found everywhere in the world. The applications are such that today a person cannot think of living without mobile applications. New companies are on the line in producing different types of mobile phones which attracts different customers and can be used for different applications. Children are also using the mobile phones without knowing the adverse affects of the mobile phones. As science and technology progresses, on one hand we get a lot of good applications but it comes with some cost which we have to pay. Technically speaking it includes lot of new technological advances into effect but it steals the time which people previously had to spend with their co- fellows. Today we can see every where people talking to mobile phones longer time than to the people who are nearby them. School children and college students are using the mobile phones simply for chatting while the classes are going on and for viewing and circulating some video materials which is not at all needed for them. These are some of the social aspects. To a electrical and electronics techno craft what is concerned for him more is the life time and usage time of the battery which powers the mobile. To a medical practitioner what is more concerned to him is the impact of biological effects made on human being by the electromagnetic radiation from the antennas used in mobile applications. Some of the worst effects are Cancers, impotency, brain tumors etc., It has been medically proved that the people who are under the influence of electromagnetic field for longer time duration are more prone to this type of disorders ,worst affected than the people who are exposed for short duration. This paper makes an attempt to address the issues of both engineers and doctors. The proposed new method in this paper can be used effectively to overcome these shortcomings.

2. EXISTING METHODS

A. Base Station and Mobile Antenna

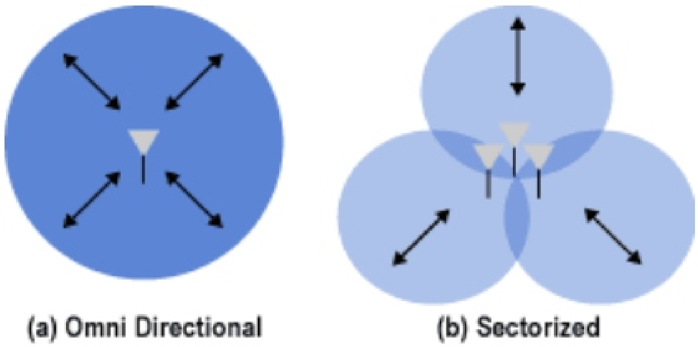

Fig 1. Non-Smart Antennas System

In all current mobile communication technologies, there is a cell, base station or base stations in each cell and number of mobile users will be attached to the base station. The base station continuously monitors the mobile users and keeps in touch with them constantly by sending pilot signals to the mobiles. The mobile receiver constantly receives the power transmitted by the base station and displays it continuously so that the user can easily view the strength of the signal. This can be treated as continuous wastage of power and continues electromagnetic radiation which increases health hazards.

B. Smart Antenna Technology

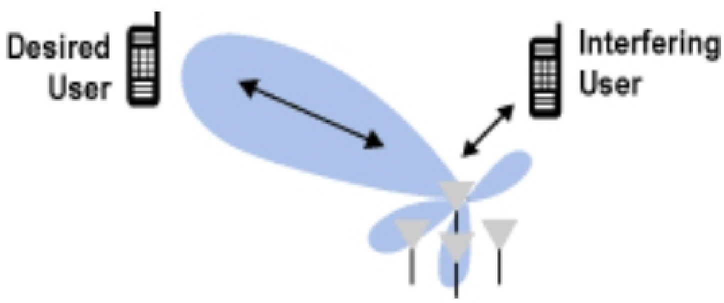

Fig 2. Smart Antenna System—Beam forming

Smart Antenna Technology uses the adaptive arrays at the base station which greatly increases the radiation in the desired direction and places nulls in the interfering user's direction. Smart antennas combined with CDMA technology promises many advantages in mobile communications. Some of them worth mentioning are increased range extension, reduced interference, increased CINR, increased data capacity throughput etc. The concept of SDMA i.e. space division multiple access greatly increases the capacity of the system to an extent beyond which it cannot be extended further for the given CINR. There are different smart antenna technologies available, plenty of beam forming algorithms are available with a wide variety of direction finding algorithms. Surely this addresses the issues of radiation and power concerns to a considerable extent and researches are still on to make the system better and efficient.

C. MIMO Technology

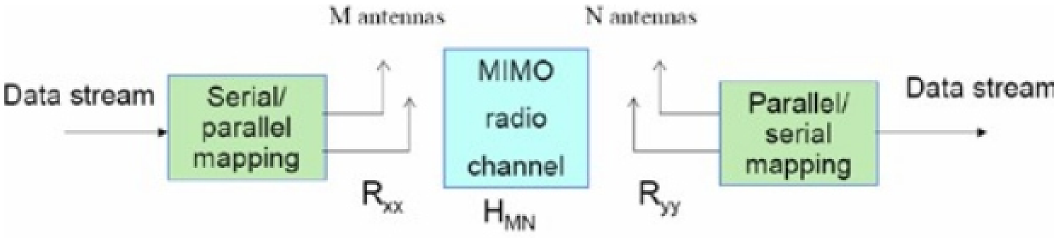

Fig 3. MIMO Concept

With the advent of latest Multi Input Multi Output (MIMO) technology, multiple antennas are used at both the transmitter side and receiver side. This uses a method of spatial diversity to increase the throughput. This can be considered as an extension of smart antenna technology with smartness placed both at the base station transmitter and mobile receivers. One problem with MIMO technology is the Eigen value should be available for each multipath for the algorithm to work efficiently. This needs the presence of lot of scattering objects and reflectors available in the path of propagation. Space time block codes are used to address some of the issues in MIMO. This technology doubles the advantages that we got with smart antennas.

3. PROPOSED METHOD

In the proposed technology the base station will be changed to green e-stations or simply green base stations (GBS) as a trend where every thing is changed nowadays towards green technology and e-applications like e-commerce etc.., . There will be no continuous radiation but there will be Radiation on Demand (ROD). The ROD technique highly improvises power conservation and reduces radiation. Likewise the mobile phones are no longer called the same way which they are previously called but they are called as green e-mobiles or simply green mobile users (GMU) . The basic requirement here is the low power global positioning systems called green global positioning system (GGPS) which identifies each and every green mobile exactly and connects with its corresponding green base stations. It has been identified that by using a unique identification number each and every mobile in this universe can be numbered. This unique numbers can be used to identify the mobile, connect to base station to produce radiation on demand (ROD) and by using smart antenna technology the adaptive beam forming can be done.

4. LEVY'S POWER CONSERVATION METHOD (LPCM)

Consider a Single green station a two green mobile users and a green low power global positioning system. When there is no communication between A and B there will be no radiation at all. The mobiles will not radiate the base station will not radiate. But there is a small low power pilot radiation from Global positioning system. When user A wants to communicate to user B, when the first button is pressed a pilot signal will be transmitted to global positing system which identifies the location of the mobile and correctly activates the base station with in the limits of A. Now the base station establishes connection with A and gets the information to which it wants to communicate. When it gets the complete information it communicates to the base station with in the limits of B through global positioning system. Once the connection between the two users is established the global positing system can be signed off and the two users will communicate through smart antennas in their base stations. Once the communication is over, the link can be removed and the mobiles can be put in the idle state. In this way unnecessary transmission and reception of continuous radiation is reduced, battery power is saved and radiation hazards are reduced. Low power global positioning system plays a vital role in this technology.

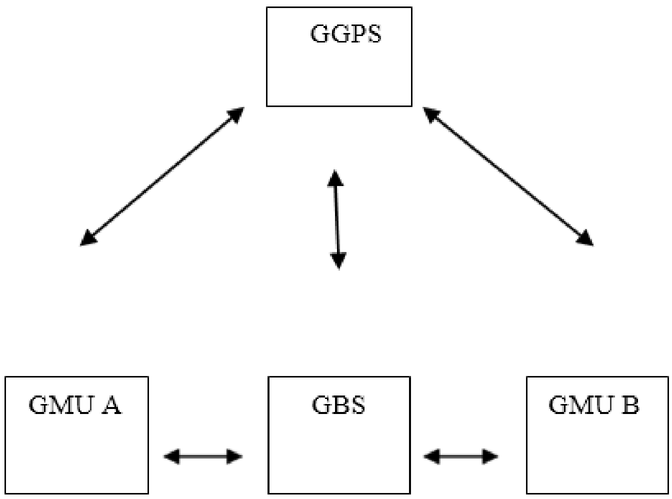

Fig 4. Levy's Power Conservation Method- Block Diagram

5. CONCLUSION

In this research article a new Green technology for mobile communication called Levy's Power Conservation Method (LPCM) is proposed. The future research effects can involve the replacement of global positioning system with the green station itself to reduce the overall cost of the system involved.

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Ion-Track based Sensors

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ABSTRACT

The sensor market is rapidly growing. With the increasing demand for better sensors of higher sensitivity and greater selectivity, intense efforts are being made to find more suitable materials with the required surface and bulk properties for use in gas sensors. Detection and quantification of gaseous species in air as contaminants (polluting gases) at low cost is becoming important. The present demand for sensors is not limited to gas sensors only. Scientists are already looking for better Physical, chemical and biological sensors and have obtained considerable success in the past few decades.

Keywords: ion track, nanodevices, sensors, physical, chemical, biological, TEMPOS, tunable electronics

1. INTRODUCTION

Over the past 20 years, a great deal of research effort has been directed toward the development of small dimensional sensing devices for practical applications ranging from toxic gas detection to manufacturing process monitoring. However, many of these efforts have not yet reached commercial viability because of problems associated with the sensor technologies applied to gas-sensing micro-systems. Inaccuracies and inherent characteristics of the sensors themselves have made it difficult to produce fast, reliable, and low- maintenance sensing systems comparable to other micro-sensor technologies that have grown into widespread use commercially. At present, the car industry has the maximum use for sensors, followed by the product processing industry, household and office equipment production, construction, machine building and aerospace industry [1]. Both sensor electronics and track-based-nano-electronics are rapidly developing areas of science and technology. Ion track based technology has been promising in the making of miniaturized sensors of all types. For this both latent and etched ion tracks can be employed.

In the last few years, a new type of electronics, based on etched tracks in insulators formed by individual or multiple swift heavy ions has been introduced. Due to the possibility of inserting any (semi)conducting material into these tracks, various active and passive electronic devices have been created. As many of these structures have sensing properties intelligent sensors have been made. One of them, TEMPOS (Tunable Electronic Materials with Pores in Oxide on Silicon) structures is currently the topic of an ever-increasing number of publications. They are a family of novel electronic structures realized on ion tracks, created by the impact of swift heavy ions of energy of the order of few hundred MeV onto dielectric layers such as SiO2, SiON etc. on Si wafers, with subsequent etching [2]. Considerable work on sensors has been done using ion track based technology and need for a comprehensive review is thus felt. The present article throws light on ion track based physical, chemical and biological sensors.

2. LATENT ION TRACK BASED SENSORS

The radiochemical changes taking place along latent tracks can be utilized to make sensors. Radiochemical changes along the ion tracks in, e.g. polycarbonate lead to an increase of - OH and other groups to which protons from the ambient readily bond transiently, thus giving rise to a slightly enhanced conductivity. This signifies that such a material acts like a hydrogen sensor [3]. By combining ion track technology with ordinary low-resolution printed circuit board lithography it is possible at low cost to create high aspect ratios via connectors, as solid plugs or consisting of bundles of sub-micron connector wires at a small total cross-section. Ion track enabled microwave circuits in flexible printed circuit boards are suggested to be used in applications like inductors, ferromagnetic resonance microwave filters, circulators and magnetoresistive sensors. Mikael Lindeberg et.al. have used two different flexible polyimide-based foils (Espandex and Kapton HN) in their work [4].

3. ETCHED ION TRACK BASED SENSORS

Various materials have been embedded in etched tracks and thus provide applications as physical, chemical and biological nano-sensors [5].

3.1 Physical sensors

The physical sensors can sense changes in variables like voltage, temperature, pressure, light intensity and magnetic field intensity etc. Ion-track-based temperature, pressure and light sensors have been built with fullerene as sensing material. In this case the proper choice of the contact material is important as many metals react with C60 to form compounds. Chromium and gold have been found to be the most suitable materials [6]. As the I/V characteristics of TEMPOS structures depends on the material which is inserted within the tracks, C60 filled TEMPOS structures have been found to be sensitive to pressure. TiO2 filled in the etched tracks of TEMPOS structures can make them record the photocatalytical activity of anatase [D. Fink, Novel Ion Track-Based Electronic Structures – An Overview (ISL Information, HMI Berlin, 2005) 2-5]. Zn-phtalocyanine TEMPOS structures have been found to be good photo sensors. With increase in light intensity the rise of current is observed depending upon the gate voltage between the surface contacts [7].

Methacryloyl-L-alanine methyl ester (MA-L-AlaOMe)/diethyleneglycol-bis-allylcarbonate (CR-39) solution cast films (100µm thick) irradiated with gold ions and etched with NaOH solution act as good temperature sensors. They swell and shrink reversibly in water between temperature ranges 60°C to 0°C. The swelling capacity of the films increases with increasing MA-L-AlaOMe content [8]. A nanowire consisting of alternating layers of a magnetic and a non-magnetic metal, e.g. cobalt and copper serve as self-contacting magnetic field sensors. Based on the giant magnetoresistance (GMR) effect, its electrical resistance decreases quadratically with increasing magnetic field. It is produced by electrochemically filling an etched track nanochannel contained in a thin polycarbonate foil films of thickness 30 µm. The films are first irradiated with heavy ions by applying a flux of 108 ions cm−2. The tracks thus formed are preferentially etched in sodium hydroxide solution to prepare cylindrical nanochannels. Co81Cu19 alloy nanowires are electrodeposited, while Co/Cumultilayered nanowires, consisting of alternating Co and Cu layers are synthesized by means of a pulse plating technique in the channels. Co81Cu19 alloy nanowires show an anisotropic magnetoresistance effect and the giant magnetoresistance of Co/Cu multilayered nanowires is appreciable [9].

A conically shaped nanopore in a polyethylene terephthalate (PET) foil can behave as voltage sensor. The pore is produced by irradiation of the foil with a single heavy ion and subsequent etching in alkaline solution. The resulting pore functions as a voltage gate and rectifies ion current due to changes of its diameter in an electrical field. Ion currents through the pore show voltage-dependent fluctuations, whose kinetics are similar as in voltage-gated biological ion channels and pores [10]. There is a technique by which it is possible to produce a planar sensor for ion channel electrophysiology from glass substrates. Apertures with diameters in the low micrometer to submicrometer range are achieved by irradiation of a glass chip with a single heavy ion and subsequent wet track etching. The function of the device is demonstrated by recordings of single channel currents mediated by the model ion channel gramicidin A in lipid bilayers spanning the micromachined aperture [11].

3. 2 Chemical sensors

The chemical sensors can sense moisture, alcohol, acetone, hydrogen, ammonia, oxygen etc. First ion-track-based sensors have been developed especially for oxygen as some biochemically important materials to be detected react with the enzyme glucose oxidase towards H2O2 which is transformed to water by anodic oxidation [12]. Such sensors can be realized in miniaturized form according to the following redox equation which describes a change of the oxidation state induced by charge transfer according to:

$O + ne^- \rightleftharpoons R$, where O is the oxidant, R is the reductant, e- is the elementary charge and n is the number of electrons transferred per reaction. This charge transfer takes may take place at the sensor electrodes which can be produced as e.g. Au nanotubules [13]. If oxygen is to be probed, the latter is reduced at a cathode to hydroxide. Both Zn-phtalocyanine and C60 based TEMPOS structures have been found to be good humidity sensors.

TEMPOS structures inserted with both polymer electrolytes and semiconductor dispersed polymer electrolytes are good humidity and ammonia sensors. This behaviour is mainly due to the increased number of protons available on the exposure to the above gases. Their selectivity, sensitivity, reversibility and response time are moderately good [14, 15].

Microporous/nanoporous polymer foils with parallel pores have found applications as sensors. Solutions of organometals can either be intimately mixed with polymer solutions that are subsequently dried and ion irradiated or they can be filled into etched tracks and then destroyed in situ by ion irradiation. Tin oxide layers that act as alcohol sensors are obtained by spin coating of Sn-ethylhexanoate solution doped with a, Sb, Pt or Ag compounds onto a substrate [16].

A sensor capable of detecting single DNA molecules has also been made. The sensor is based on a single nanopore prepared in a polymer film by a latent ion track-etching technique. For this purpose, a polymer foil was penetrated by a single heavy ion of total kinetic energy of 2.2 GeV, followed by preferential etching of the ion track. DNA molecules were detected as they blocked current flow during translocation through the nanopore, driven by an electric field. The nanopores are highly stable and their dimensions are adjustable by controlling etching conditions. For detecting DNA, conical nanopores with opening diameters of 2 μm and 4 nm were used. The nanopore sensor was able to discriminate between DNA fragments of different lengths [17].

3.2 Biological sensors

The biological sensors can sense the germs, viruses, proteins, hormones, enzymes, sterilizing efficiency etc.). Lately, a new type of protein biosensor based on a single conically shaped gold nanotube embedded within a polymeric membrane prepared by the track etching technique has been reported [18]. There are several applications of biosensors in food analysis. In food industry optic coated with antibodies are commonly used to detect pathogens and food toxins. The light system in these biosensors has been fluorescence, since this type of optical measurement can greatly amplify the signal.

In many industries gases have become increasingly important as raw materials and for this reason among others it has become very important to develop highly sensitive detectors. Such devices should allow continuous monitoring of the concentration of particular gases in the environment in a quantitative and selective way. With the advent of latest technology more advanced gas sensors will be fabricated in the future.

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Application of Taguchi Approach for Optimization of CNC Wire Electrical Discharge Machining Process Parameters

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ABSTRACT

*In this research work, through the Taguchi methodology found the optimum process parameters for CNC wire electric discharge machining (WEDM). The object of the research paper to optimize the MRR and SR of work piece high chromium high carbon (HCHC) die steel tool. This methodology based on Taguchi's, analysis of variance (ANOVA) and signal to noise ratio (S/N Ratio) to optimize the CNC WEDM process parameter. The design of experiment for machining process control parameter are Voltage(A), Discharge current(B), Pulse duration(C), Pulse frequency(D) and Wire Tension(E) L27 (3*5) standard orthogonal array design of experiment three level and five parameter A, B,C,D and E respectively for each combination we have conducted one experiment. We have found the optimum results for CNC WEDM through the Signal to Noise ratio (S/N ratio).*

Keywords: CNC WEDM, Taguchi' method, ANOVA, MRR, SR , S/N Ratio.

INTRODUCTION

The Wire-cut EDM (WEDM) uses a slender wire diameter of the order of 0.15 –0.30 mm as an Electrode. Wire travels through the work piece from upper and lower wire guides. In wire- cut EDM process the spark is occurring between continuous traveling wire and work piece. Here wire Acts like a band saw, but sparks instead of teeth do the cutting. The variations in the machining Parameters, such as the gap voltage, wire feed rate, gap current, and duty factor, greatly affect the Measures of the machining performance, for example, the SR and the MRR. Therefore, proper Selection of the machining parameters can result in better machining performance in the electrical Discharge machining process. In this study, a Reciprocating Wire-cut EDM machine, Electronica makes, EZZYCUT – PLUS model was used as the experimental machine. Cylindrical hard copper wire with a diameter of 0.25 mm was used as an electrode to erode a work piece of High-Carbon-High-Chromium (HCHC) die steel plate of the thickness of 30mm. The schematic diagram of the experimental setup is shown in Fig. 1. The work piece and electrode were separated by a moving dielectric fluid i.e. blend of tap water and coolant oil (S100) in a ratio of 20:1. The variation of MRR and SR with machining parameters and optimization of machining settings for maximum MRR minimum SR should be investigated experimentally and the obtained results should be interpreted and modelled statistically to understand closely the behaviour of machining rate and accuracy in CNC WEDM In this study, the effect of the machining parameters and their level of significance on the MRR and SR are statistically evaluated by using analysis of variance

(ANOVA). The settings of machining parameters were determined by using Taguchi experimental design method.

METHODOLOGY

A. Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) and F-test (standard analysis) are used to analysis the experimental data as given follows

Notation:

Following Notation are used for calculation of ANOVA method

C.F. = Correction factor

T = Total of all result

n = Total no. of experiments

ST = Total sum of squares to total variation.

Xi = Value of results of each experiments (i = 1 to 27)

Sx = Sum of the squares of due to parameter x (X = A, B, C, D,E)

Nx1, NX2, NX3 = Repeating number of each level (1, 2, 3) of parameter

X XX1, XX2, XX3 = Values of result of each level (1, 2, 3) of parameter

X FX= Degree of freedom (D.O.F.) of parameter of X

fT = Total degree of freedom (D.O.F.)

fe = Degree of freedom (D.O.F.) of error terms

VX = Variance of parameter X

Se = Sum of square of error terms

Ve = Variance of error terms

FX = F-ratio of parameter of X

SX' = Pure sum of square

CX= Percentage of contribution of parameter

X Ce = Percentage of contribution of error terms CF = T2/n

ST = Σ i=1 to 27 Xi2 – CF

SX = (XX12/NX1 + XX22/NX2 + XX32/NX3) – CF

FX = (number of levels of parameter X) – 1

fT = (total number of results)-1

fe = fT - Σ fX

VX = SX/fX

$Se = ST - \Sigma SX$

$Ve = Se/fe$

$FX = VX/Ve$

$SX' = SX - (Ve*fe)$

$CX = SX'/ST * 100\%$

$Ce = (1 - \Sigma PX)*100\%$

SIGNAL TO NOISE RATIO CALCULATION

Quality Characteristics:

S/N characteristics formulated for three different categories are as follows:

Larger is Best Characteristic:

Data sequence for MRR (Material Removal Rate), which are higher-the-better performance characteristic are pre-processed as per Eq.1

$$S/N = -10 \log ((1/n) (\Sigma(1/x^2)) \qquad \text{.............................. 1}$$

Nominal and Smaller are Best Characteristics

Data sequences for SR , which are lower-the-better performance characteristic, are pre- processed as per Eq.1 &2

$$S/N = -10 \log (x/s2x) \qquad \text{........................... 2}$$

$$S/N = -10 \log ((1/n) (\Sigma(x2)) \qquad \text{......................3}$$

Where y^ is average of observed data x, sx2 is variance of x, and n is number of observations.

EXPERIMENTAL SET UP AND WORK PROCEDURE:

Equipment:

Wire Cut EDM works on the principle of Electrical Discharge Wire Cutting (EDWC), most commonly known as Wire Cut EDM. It is a spark erosion procedure to produce complex 2- Dimentional and 3-Dimentional shapes through electrically conductive work pieces. This machine is used only for manufacture parts which are electrically conductive. Wire Cut EDM differs from conventional EDM is that a thin, 0.05-0.3 mm in diameter wire used for manufacturing of our product.

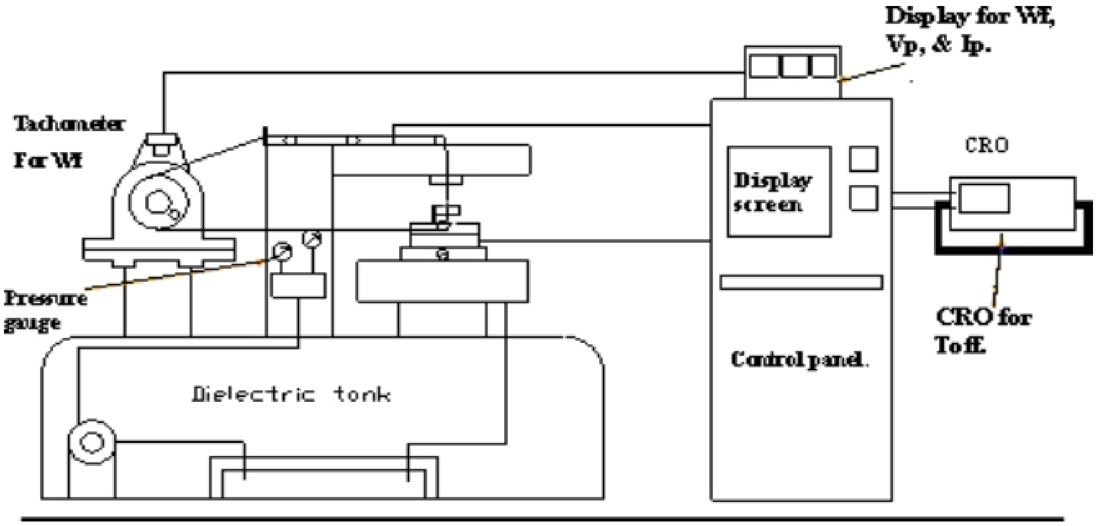

Figure 1. Schematic Diagram of EzeeCutPlus Wire EDM

Material:

In this investigation, we used work piece material High Chromium High Carbon die steel (HCHC) in this experiments. Which have cold work tool steel with substantial amounts of Chromium and Carbon (HCHC) tool steels offer good dimensional accuracy, wear resistance and machinability.

Design of Experiments

The experimental layout for the machining parameters using the L27 orthogonal array was used in this study. This array consists of five control parameters and three level, as shown in table I In the taguchi method, most all of the observed values are calculated based on 'the higher the better' and 'the smaller the better'..Thus in this study, the observed values of MRR, and SR were set to maximum, and minimum respectively.

Table I: Design Scheme of Experiment of Parameters and Level

	Level				
Control Parameters	1	2	3	Units	Observed Values
Voltage [A]	120	140	160	Volt	1. Material Removal
Discharge current [B]	16	24	32	Amp	Rate (mm^3/min)
Pulse duration [C]	6	8	10	µsec	2. Surface Roughness
Pulse frequency [D]	60	70	80	KHz	(Ra)
Wire Tension [E]	1100	1200	1300	gm	

Table II: Observed Values of MRR and SR

Experimental trial	A	B	C	D	E	Response of MRR (mm^3/min)	Response of SR(µm)
1	1	1	1	1	1	0.995	4.313
2	1	1	1	1	2	0.976	3.564
3	1	1	1	1	3	0.882	3.432
4	1	2	2	2	1	0.685	4.001
5	1	2	2	2	2	0.692	3.978
6	1	2	2	2	3	0.783	3.671
7	1	3	3	3	1	0.829	3.984
8	1	3	3	3	2	0.925	3.986
9	1	3	3	3	3	0.872	3.789
10	2	1	2	3	1	0.534	3.981
11	2	1	2	3	2	0.672	4.101
12	2	1	2	3	3	0.875	3.981
13	2	2	3	1	1	0.892	3.781
14	2	2	3	1	2	0.91	3.789
15	2	2	3	1	3	0.89	3.897
16	2	3	1	2	1	0.801	2.988
17	2	3	1	2	2	0.981	2.987
18	2	3	1	2	3	0.785	3.981
19	3	1	3	2	1	0.689	3.895
20	3	1	3	2	2	0.769	3.9
21	3	1	3	2	3	0.929	4.106
22	3	2	1	3	1	0.983	3.005
23	3	2	1	3	2	0.871	3.95
24	3	2	1	3	3	0.898	3.671
25	3	3	2	1	1	0.987	4.001
26	3	3	2	1	2	0.911	3.123
27	3	3	2	1	3	0.907	3.91

TAGUCHI ANAYSIS FOR MRR

Anaysis of MRR using MINITAB software

Taguchi Analysis: Response of MRR versus A, B, C, D, E

Larger is better

Table III. Response Table for Signal to Noise Ratios for MRR

Level	A	B	C	D	E
1	-1.4944	-1.9515	-0.8694	-0.6600	-1.8696
2	-1.898	-1.524	-2.2713	-2.1069	-1.4239
3	-1.1346	-1.0515	-1.3863	-1.7600	-1.2335
Delta	0.7635	0.9000	1.4019	1.4469	0.636
Rank	4	3	2	1	5

Table IV: Response Table for Means for MRR

Level	A	B	C	D	E
1	0.8488	0.8134	0.908	0.9278	0.8217
2	0.8156	0.8449	0.7829	0.7904	0.8563
3	0.8827	0.8887	0.8561	0.8288	0.869
Delta	0.0671	0.0752	0.1251	0.1373	0.0473
Rank	4	3	2	1	5

TAGUCHI ANAYSIS FOR SR

Taguchi Analysis: Response of SR versus A, B, C, D, E

Smaller is better

Table V. Response Table for Signal to Noise Ratios For SR

Level	A	B	C	D	E
1	-11.71	-11.84	-10.92	-11.46	-11.47
2	-11.36	-11.45	-11.71	-11.36	-11.34
3	-11.38	-11.15	-11.82	-11.63	-11.64
Delta	0.35	0.69	0.91	0.27	0.31
Rank	3	2	1	5	4

Table VI. Response Table for Means for SR

Level	A	B	C	D	E
1	3.858	3.919	3.543	3.757	3.772
2	3.721	3.749	3.861	3.723	3.709
3	3.729	3.639	3.903	3.828	3.826
Delta	0.137	0.28	0.36	0.105	0.118
Rank	3	2	1	5	4

RESULT AND DISCUSSION:-

The following discussion focuses on the different of process parameters to the observed values (MRR and SR) based on the Taguchi methodology.

Material Removal Rate (MRR)

Main effects of MRR of each factor for various level conditions are shown in figure2 and 3.

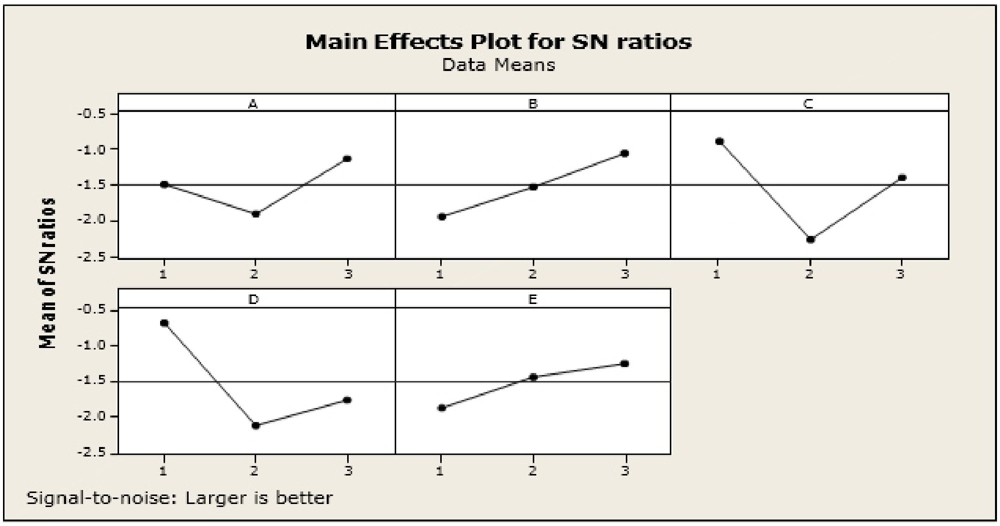

Fig.2 Main Effects Plot for S/N ratios for MRR

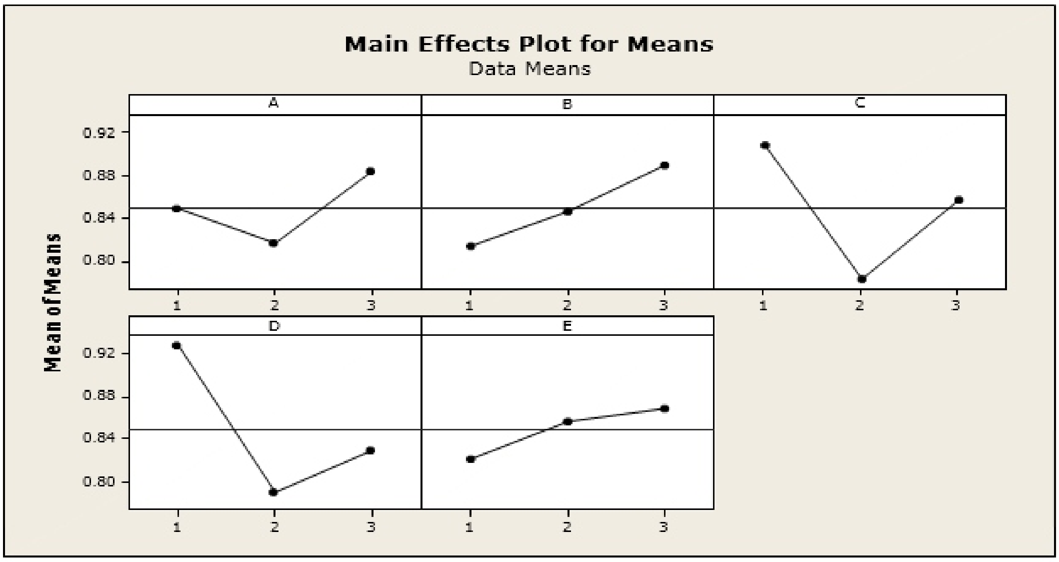

Fig. 3 Main Effects Plot for Means for MRR

With the above graph for S/N ratio for MRR and Mean for MRR we have found the optimal parameter setting A3B3C1D1E3 which is voltage at level 3 (160 Volt), Discharge current at level 3 (32 Amp), Pulse duration at level 1 (6 µsec), pulse frequency at level 1 (60 KHz), Wire tension at level 3 (1300 gm).

Surface Roughness (SR)

Figure 4 and 5 evaluates the main effects of each factor for various level conditions.

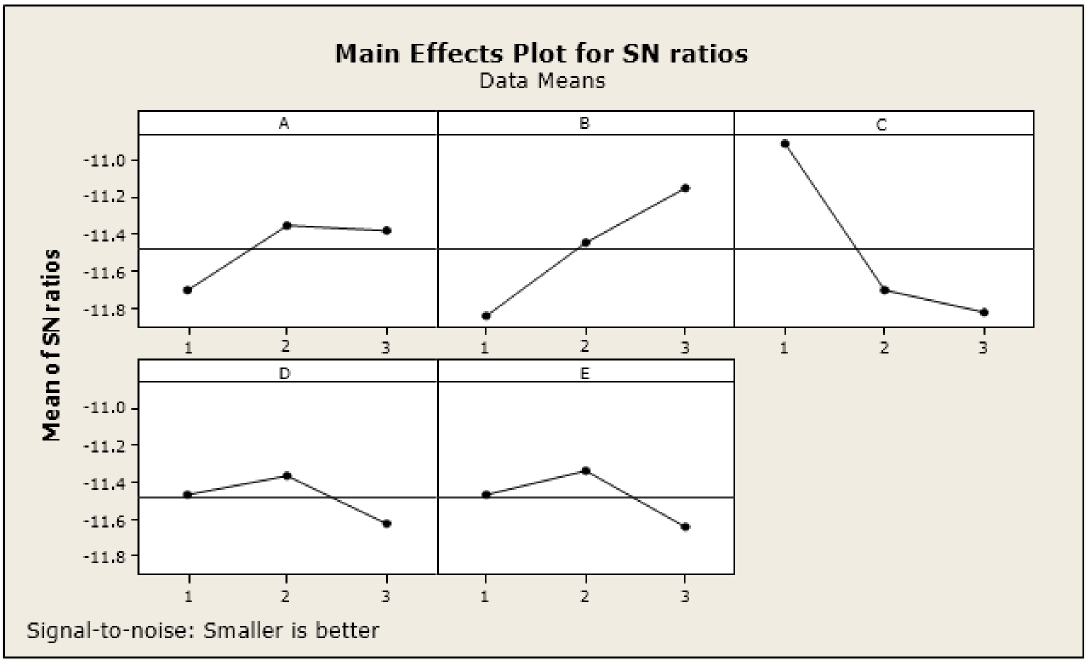

Fig . 4 Main Effects Plot for S/N ratios for SR

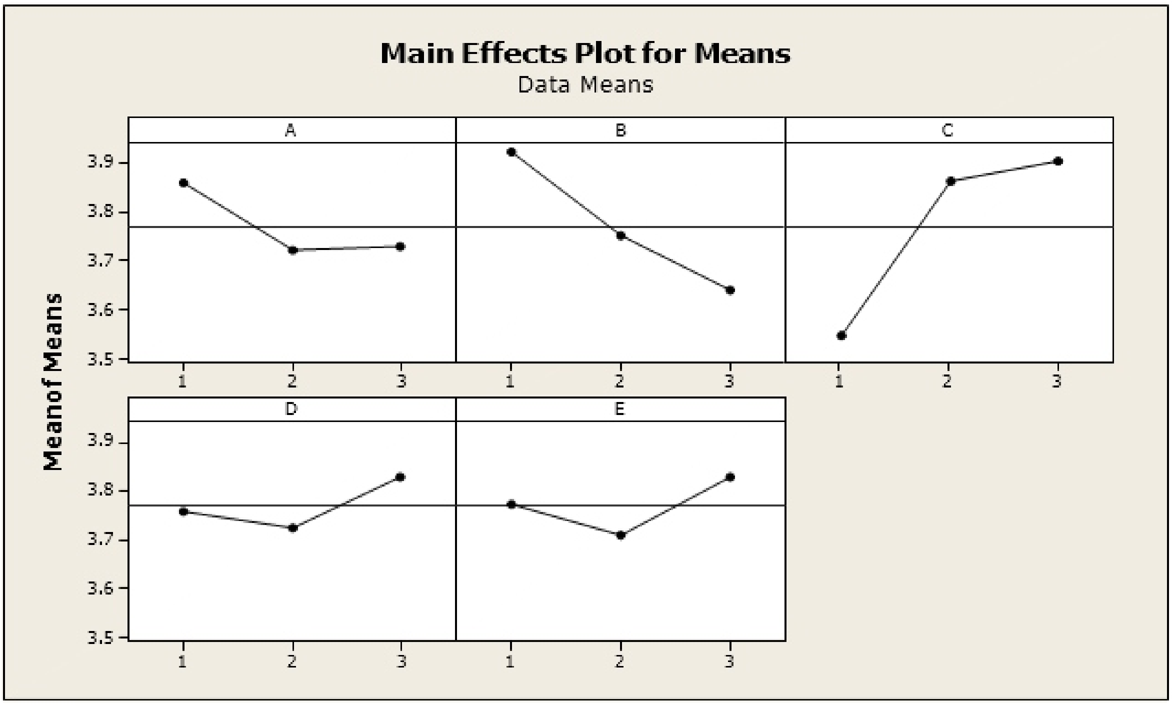

Fig . 5 Main Effects Plot for Means for SR

With the above graph for S/N ratio for SR and Mean for SR we have found the optimal parameter setting A2B3C1D2E2 which is voltage at level 2 (140 Volt), Discharge current at level 3 (32 Amp), Pulse duration at level 1 (6 μsec), pulse frequency at level 2 (70 KHz), Wire tension at level 2 (1200 gm).

CONCLUSION

Based on Taguchi analysis for Material removal rate, pulse frequency is the most significant factor because it is having 1 rank in case of MRR and predicted optimal parameter setting is A3B3C1D1E3. According to predicted optimal setting we have conducted the experiment and MRR found 0.9827 mm3/min. In the case of surface roughness pulse duration is the most significant factor because it is having 1 rank in case of SR and predicted optimal parameter setting are A2B3C1D2E2. According to predicted optimal parameter setting for SR we have found 2.987 µm that shows the successful implementation of Taguchi analysis.

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