Performance Evaluation/Analysis of Distributed Generation System

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Abstract— This work deals with hybrid distributed generation systems with various used simulation tools and analyzes the performance of distributed generation system. These distributed generation source can perform on single source or multiple source. Since sometimes there may be a problem of fault then at that time there is a requirement to fulfill the operation of power production and continuity of electricity. Hence hybrid distributed generation systems are introduced which enhance the continuous and reliable power and improve the efficiency. In various isolated sites which are isolated from cities they prefer diesel power generation. But this production becomes costly and less efficient and difficult to access the electricity grid. Due to increase rise in fuel price there may be problem to produce reliable electricity then renewable sources have been employed to overcome emission of green house gas and cost reduction in the market. There is also variability of renewable power sources due to weather conditions which may not be correlated with the load demand. So this paper deals with different scenario of hybrid distributed generation systems with their operating tools to evaluate the behavior of hybrid renewable systems.

Keywords- Fuel cell; HOMER; Hybrid; INSEL; Solar; RAPSIM; Thermal; TRNSYS

I. INTRODUCTION

The demand energy is growing as load demand is increasing so keeping all consideration distributed generation system has been introduced. Distributed generation is approach of small scale power generation at customer site [4]. These are installed in such a way that it performs efficient and keeps the continuity of supply to the load customers. This idea has reduced cost of power generation from the point of view of economics about electricity markets. Basically DG sources are not supposed to generate, transmit, distribute and balancing demand and supply. There are various applications of DG sources in technology development by providing storage of electricity [1] [3].

Unlike traditional power plants distributed generation power plants prefer a method in which a part of power is generated, transmitted and distributed at the consumer side. The term distributed generation can be addresses as embedded system, dispersed generation or decentralized generation. Increasing load demand employs these types of power plants keeping all the weather circumstances provide better and reliable energy at the customer side[7][9]. There are various types of system which employ conventional and non-conventional energy sources such as solar, wind, hydro, thermal, fuel cell etc. All the sources are used under consideration of new and latest technology. Because in advanced technologies there may be low chance of fault at the customer side and provide continuous power supply.

Nowadays with keeping in mind of technical aspects economic benefits can be achieved by using distributed generation sources. The advantages can be enhanced by choosing bets optimal location and its sizing. Due to improper location and sizing it creates problem at the customer side for achieving power [2] [5].

There are many challenges like environmental and technical restrictions in the traditional power plants. Most of the times there were large usage of fuel cells which make high maintenance and operating costs. So that distributed generation systems with latest technologies have been employed. In distribution networks there are some issues like power losses, power quality, reliability and voltage control.

The installation of distribution systems perform in all the aspects to provide efficient power to the customer side [9]. Distributed generation allocation also includes distributed generation planning for the better operation of plants. Since there are many objectives kept before installation of distributed generation systems to approach better power quality and reliability of energy. There are multi planning objectives based on which distributed generation plants operate. So according to the selective objectives distributed generation plants use selective optimization method to locate the best optimal location and sizing of distributed generation power plants [8][11].

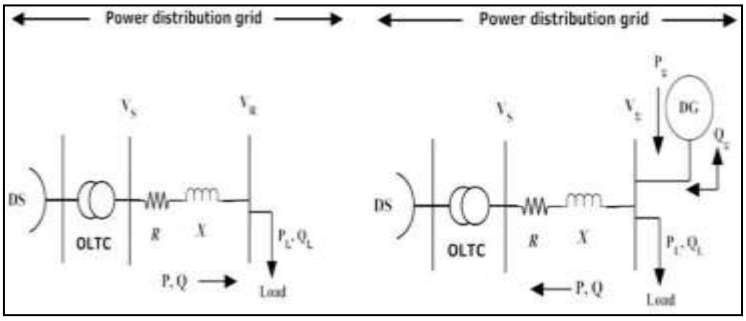

Figure 1. Structure of conventinal distribution feeder with and without DG [16].

In conventional distribution systems there are some methods to regulate voltage.

- Using on load tap changer
- Using switched capacitors
- Using step voltage regulator

There are alternative methods with some valuable objectives to improve the quality of power and reliable operation:

- Reduction of generation during low demand
- Controlling of reactive power by using reactive compensator
- Voltage controlling by area based OLTC
- Inverters at DG sites
- Energy storage

So there are numerous solutions to compensate the problem enhanced into tradition al power plants and to achieve the best optimal location of distributed generation power system [15] [26]. In this paper, distributed generation systems have been experimentally carried out for remote areas for developing better and sustainable energy and to provide the beneficiaries to the consumers. Various techniques with reactive power compensating devices have been developed to control and monitor the operation of DG system. Many researchers and academicians are dealing with these areas to give a new and innovative algorithm for reducing the cost of fossil fuels and transportation issues for the fuels.

II. HYBRID DISTRIBUTED GENERATION SYSTEM

There are two schemes of hybrid power systems such as centralized and decentralized or distributed. The first concern of centralized power system is to ensure the continuity of generation system during the presence of fault or other specific critical load [14] [17]. To perform that massive power conditioning unit installed to operate all the beneficial power proceeding from each source.

Figure no.2 shows the centralized power system scheme in which this consists of photovoltaic energy sources and the power containing system with dc to ac inverter and then transmits energy to the ac load side. In decentralized power system scheme a few separate power conditioning unit has been installed to overcome the problems of centralized power system in parallel with reliable and improved flexibility [16][18][33].

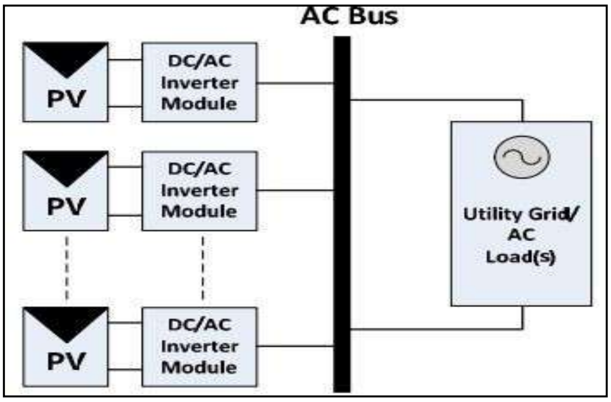

Figure 2. Centralized power system scheme [22].

In figure 3 it shows the decentralized power systems with fast and precise load sharing among the units with dc to ac inverter module and energy is transmitted to the utility grids. Hybrid distributed generation systems can be connected as grid-connected and stand-alone hybrid mode system. So these system configuration additional power conditioning devices to ensure the quality of power and synchronized with grid operation with regional standards [19][20].

These types of arrangements produce complex configuration but fulfill the all possibilities for better operation of hybrid power system. There many energy sources like wind, solar, hydro, thermal, fuel cell etc. which also operate in hybrid generated mode and perform to achieve reliable and efficient power. But there are some major and environmental aspects which affect the performance of hybrid power system.

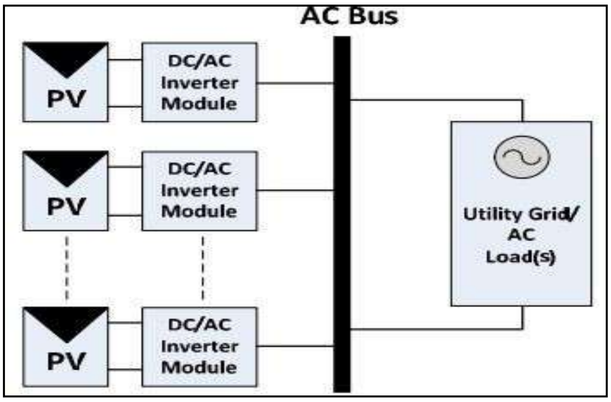

Figure 3. Decentralized power system scheme [20].

III. SOLAR WIND HYBRID POWER SYSTEM

There are two types of sources like conventional and non- conventional energy sources which configure the systematic structure of hybrid power system. These are configured in such a manner that if one source breaks down so other energy source continues the operation with reliability and sustainability. In solar PV-wind hybrid system, solar PV system comprises of PV modules which changes solar energy into electrical energy. The dc-dc converters play major role to convert dc electricity into ac power and alters the voltage to synchronize along with the electrical appliances. The dc- dc converter may be of different type such as buck converter, boost converter or buck- boost converter [30][31].

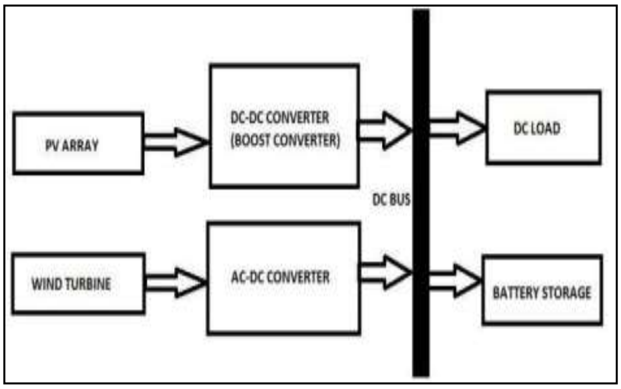

Figure 4. Centralized power system scheme [30].

Wind system converts the wind energy in to electricity in which generator is associated to the shaft of the blades that changes mechanical or potential energy into electrical energy [28][29]. The turbines are categorized as depend upon rotating axis of blades such as vertical axis and horizontal axis. Hence in order to do continues operation energy is accumulated in battery and delivered to the required load.

IV. SOLAR PHOTOVOLTAIC THERMAL HYBRID POWER SYSTEM

In solar photovoltaic and thermal hybrid power system when the solar radiation is high then the warmth of photovoltaic cells can be reached at 40 degree and it’s above which results in reduced efficiency of the entire hybrid power system. Electrical conversion efficiency reduces between the ranges of 0-25 to 0.5 percent per one degree temperature increment. So to overcome this problem solar photovoltaic and thermal hybrid power system has been introduced in which it employs thermal absorber which consists of definite number of pipes placed below the photovoltaic panels to consume the thermal energy [31][33].

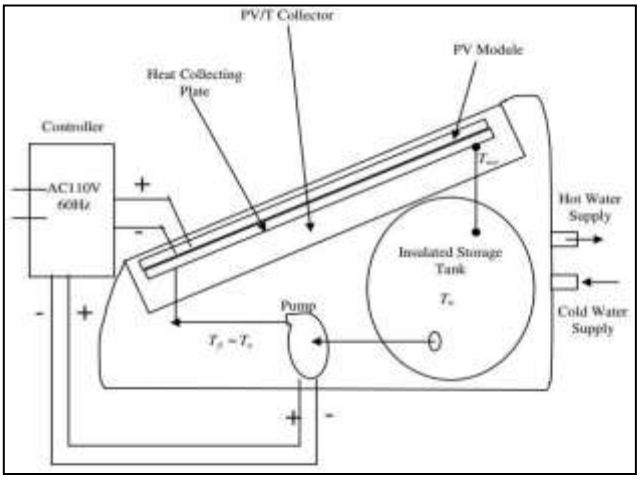

Figure 5. Solar photovoltaic thermal power system scheme [28]

There is also some categorization of solar PV/Thermal power system as shown below it shows the different types of PV/T system.

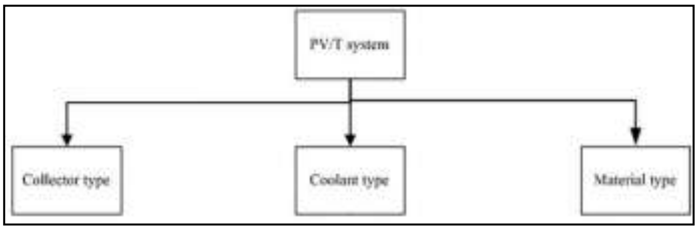

Figure 6. Classification of PV/T power system scheme [17]

Further the collector type is classified into two forms such as flat type and concentator type. The concentrator type is categorized into three types as dish type, fresnel lens and parabolic trough. The coolant type PV/T system may be of three types such as PV/T water collector, PV/T air collector and PV/T combined collector of both air and water. So these are the classification of solar PV/Thermal system which configure into various modes and perform the function to achieve better and reliable power.

Due to presence of soft computing techniques the performance of solar PV and thermal system becomes better. This hybrid system integrates to utilize thermal energy and electrical energy. Sometimes these schemes are also preferred as building integrated photovoltaic solar scheme and building integrated photovoltaic thermal scheme [30].

V. SOLAR PHOTOVOLTAIC FUEL CELL HYBRID SYSTEM

This hybrid system employs the solar photovoltaic cell and fuel cell as shown in below schematic diagram. It comprises of PV array, unitized regenerative fuel cell, inverter, dump load, bus system and electrical load. Then the output voltage of solar photovoltaic module is sustained to the dc bus when sun light is available. When the power is accessible from any source, it operates the electronic load during peak hours which could drive unitized regenerative fuel cell to split water into hydrogen and oxygen [29] [27]. The converter transforms the dc power into ac power from solar photovoltaic cells to adjoin with load demand.

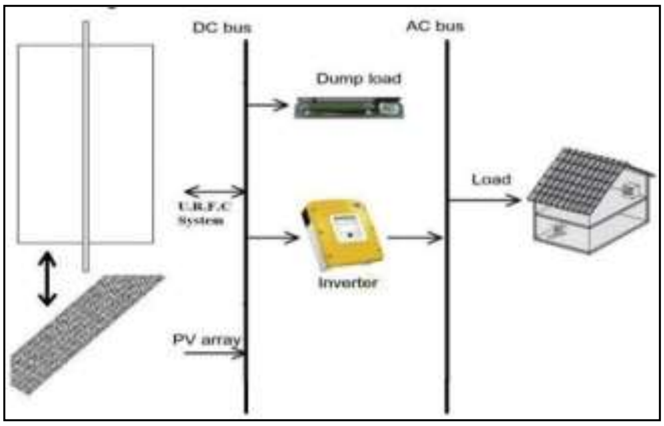

Figure 7. Solar PV/fuel cell power system scheme [25]

VI. SIMULATION SOFTWARE TOOLS

Since hybrid power schemes are being exploited for transmitting electrical power to rural, urban and remote areas to conquer the problems of individual energy source. It incorporates with two or more energy sources based on conventional or non- conventional energy sources. Due to multiple power generation system, it becomes entirely convoluted and need to be figured-out and simulated thoroughly. Thus it can be accomplished with the help of software tools for the designing, analysis, economic viability and optimizations.

The simulations are performed by using MATALB/SIMULINK environment. The parameters are taken for solar PV system as number of cells are 36, voltage at maximum power point is 13.5 volt, current at maximum power point is 2.9 A and maximum output power is 31 watt. The results are obtained with comprising of open circuit voltage of 17 volt, short circuit current of 15A and number of cells are 36. To overcome these distortions or disturbances some FACTS devices have been employed and following results are obtained.

Dynamic voltage restorer is one of the FACTS useful devices which are connected with line in series through transformer and voltage based source inverter containing common dc link capacitor. In DVR system the impedance is taken as combination of components like resistance and capacitance by taking 1 ohm and 100 µf.

The impedance of DVR system depends upon the fault level of load bus so when the system voltage drop occurs DVR injects a voltage through injection transformer hence load voltage can be maintained easily.

Hence we can write injected voltage mathematically as:

$V_{DVR} = V_L + Z_{TH} * I_L$
V_{TH}……………………………………………………………………….……….(1)

Where

V_{DVR} = voltage at DVR
V_L = load voltage
Z_{TH} = load impedance
V_{TH} = voltage at fault condition

The current at load side can be written as:

$I_L = [P_L + jQ_L]/V$…………………………………………………………………….…..(2)

If we consider load voltage as reference voltage then we may write eq. (1) further-

$V_{DVR}(\cos\varphi + j\sin\varphi) = V_L (\cos 0 + j\sin 0) + Z_{TH} . I_L (\cos(\psi - \Theta) + j \sin(\psi - \Theta)) - V_{TH} (\cos\alpha + j \sin\alpha$…………………………………………………………………………………………..….(3)

From the above equations angles φ, ψ and α are the phase angles of V_{DVR}, Z_{TH} and V_{TH}.

Now the power factor of the load can be written as:

$\Theta = \tan^{-1} (Q_L/P_L)$………………..…………………………………………………….……..(4)

Hence the injected complex power of DVR can be written as:

$S_{DVR} = V_{DVR} I_L$…………………………………………………………………………………(5)

After providing supply, we get three different voltages such as grid voltage, load voltage and injected voltage as shown in figure no. 8.

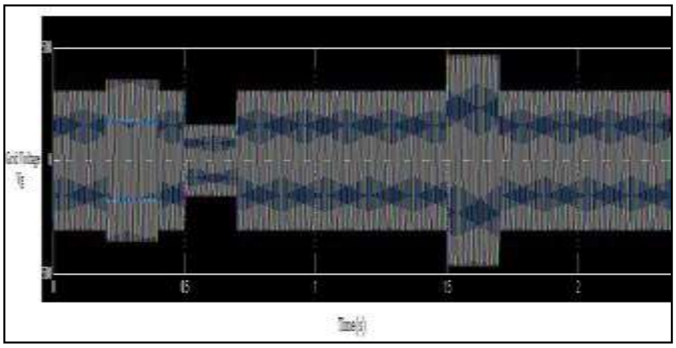

Figure 8. Grid voltage

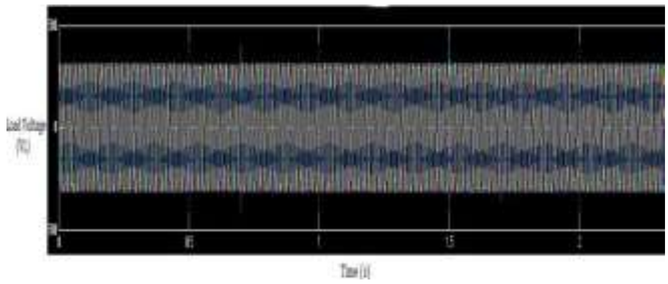

Figure 9. Load voltage

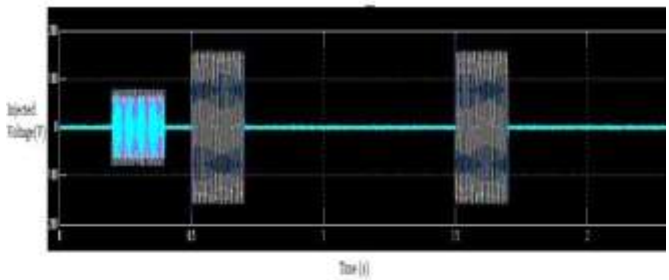

Figure 10. Injected voltage at source side

There are many software tools like HOMER, HYBRID2, RETscreen, iHOGA, INSEL, TRNSYS, HYBRIDS, RAPSIM, SOMES, SOLSTOR, HySim, HybSim, HYSYS etc. All these software perform for different energy sources and use numerous computer platforms. These software or appliances are required to overcome the problem solving in designing, analyzing and optimization of hybrid energy systems.

Table.1 shows list of software tools with different aspects. In these paper simulation results of solar PV modules with different FACTS devices have been demonstrated and overcome the problems of distortions with interconnection with DG sources. Here only solar PV array has been introduced and obtain the results with keeping all weather parameters constant under different solar irradiance.

TABLE I. LIST OF SOFTWARE TOOLS

Software	Developed By	Computer Platform	Availability
HOMER	NREI 1993	Windows visual C++	Free www.homernergy.com
HYBRID2	University of Massachusetts 1994	Windows XP visual BASIC	http://ceere.org/rerl/rerl_hybridpowert.html
RETScreen	Ministry of Natural Resources 1998	Windows 2000, XP	Free http://retscreen.net/
iHOGA	University of Zaragoza, Spain	Windows XP	Free http://www.unizar.es/rdufo/hoga-eng.htm
INSEL	German University of Oldenburg	Windows Fortran and C/C++	Priced www.insel.eu

Software	Developed By	Computer Platform	Availability
TRNSYS	University of Wisconsin and University of Colorado 1975	Windows Fortran code	Priced http://trnsys.com/
HYBRIDS	Solaris Homes	Windows spreadsheet based software	Unknown
RAPSIM	University energy Research Institute 1996	Windows	Unknown
SOMES	Utrecht University 1987	Windows Turbo Pascal	Unknown
SOLSTOR	SNL 1980s	Windows Fortran	Not used now
HySim	SNL 1980s	NA	Not used now
HybSim	SNL	NA	Unknown
HYSYS	Wind Technology Group. Spain	NA	Unknown
SOLSIM	Fachhochschule Konstanz	Windows	Not available

VII. Capability of Software Tools

As we have different software tools for estimation of distributed generation systems. The capability of tools need such as shown below:

1. Requirement of input data and input backing capability
2. Modeling capabilities of thermal and electrical supply technology
3. Controlling and optimization of output
4. Capability modeling for storage
5. Tools preference option

A. *Requirement of Input Data and Input Backing Capability*

There are requirements of different levels of input data for various tools. These tools require like demand energy profiles and characteristics of system. Some of the tools have embedded functions role which help in extracting input data set and support both manually and generated input data for calculation.

B. *Modeling Capabilities of Thermal and Electrical Supply Technology*

When the range of supply technology changes, tools also vary. Since there are most of the tools are available for modeling of electrical and thermal supply system. In these systems district heating may be available in the tools which presents an estimated heat loss. Then district heating is a factor which has a potential to increase efficiency of energy system and enhance flexibility for effectively using of waste heat with the help of thermal storage. Below table II describes technology of electrical and thermal supply for various software tools.

TABLE II. ELECTRICAL AND THERMAL TECHNOLOGY

Tools	Electrical Supply	Thermal Supply	District Heating
HOMER	CHP, D, G, Gr	CHP, FBo	No
HYBRID	D, Wi, PV	None	No
iHOGA	D, H, PV	None	No
H2RES	B, D, H, PV	FBo, EBo	No
SimRen	H, Wi, Geo	CHP	No
Energy PRO	B, D, Gr, H, PV	CHP, ST, HP	Yes
Energy PLAN	B, D,T,Wa,Wi	CHP, ST, HP	Yes
DER-CAM	CHP, PV, Wi	EBo, FBo, HP	No

***Keywords**: CHP (combined heat and power plant), PV (photovoltaic cell), H (hydro), T (tidal), EBo (electric boiler), FBo (fuel boiler), Wi (waste incineration), HP (heat pump), B (biomass power plant), Gr (grid), ST (solar thermal), D (diesel plant), G (gas plant), Geo (geo-thermal)*

C. Controlling and Optimization of Output

Various software tools focus on numerous aspects of system performance. Most of the tools are cost effective from the point of energy market interaction; some of the tools are fuel consumption, energy-demand matching and energy production. Operational optimization is a method which optimizes at each step of time and satisfies objective function related to cost and emission. The operational optimization is used as non-chronological for some tools like in EnergyPro in which total calculation time is examined for supply cost and it measures an optimized schedule of energy supply. From the point of discharge from energy storage like in HOMER which includes average energy cost, maintenance cost and efficiency [34].

D. Capabilty Modeling For Storage

In this section the storage capabilities are modeled which shows electrical and thermal storage for different software tools.

TABLE III. CAPABILITY OF STORAGE MODELING

Tools	Electrical Supply	Thermal Supply	Fuel Synthesis
HOMER	FB, PH, SSM	No	H
HYBRID2	EKiBAM	No	No
iHOGA	KiBAM	No	H
Energy PRO	PH, SSM	CS, MB	BG, H
Energy PLAN	PH, SSM	SSM, STS	BG, H
SimREN	Yes	No	No
HOMER	FB, PH, SSM	No	H
HYBRID2	EKiBAM	No	No

Keywords: *PH (pumped hydro model), SSM (simple storage model), CS (cold storage model), MB (moving boundary model), BG (bio gas), H (hydro), KiBAM (kinetic battery model), EKiBAM (modified kinetic battery model).*

Electrical storage is a general term which is used for energy storage from electro-chemical reaction (Li-ion, lead acid battery) and electro magnet such as capacitors etc. Similarly thermal storage permits energy storage from sources like latent heat, cold storage and radiator [34].

E. *Tools Preference Option*

The tool selection process must be precise and compatible with its desirability and user friendly. Cost is the most vital factor among all selection options which depends upon the resources which are easily accessible to the user. Some of the tools are free available for students and some are priced by government agency which are available like at 3500 +EUR for EnergyPRO and 500-2000 USD for HOMER. Below table shows the selection option of software tools with cost considerations.

TABLE IV. SELEDTION OPTION FOR SOFTWARE TOOLS

Tools	Cost	User Friendly
HOMER	Free 2 week trial, 500-2000 USD	High
HYBRID2	Free	Not available
iHOGA	Free for educational use	Medium
Energy PRO	3500+ EUR	High
Energy PLAN	Free	High
SimREN	Not available	Not available
DER-CAM	Free	Medium
HOMER	Free 2 week trial, 500-2000 USD	High

CONCLUSION

In this paper we have scanned different software tools with different terminologies and the performance of software tools has been analyzed by considering parameters like input and output data requirements, selection process of tools, storage capabilities, controlling and optimization of output. These are done as to be designed with low cost and resilient features. Different capabilities of tool are documented in tabular form. This helps us for improving more upgrading of models and provides flexibility to the users.

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