IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

Dynamic Model of Micro Turbine Generation System for Islanding Operation and Power Quality Enhancement with HVDC Converter

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Abstract: Distributed generation is very important role in electrical power system in near future. Distributed energy which produce electricity from small energy sources. the energy sources are directly connected to low or medium voltage distribution systems. The insertion of DG system into existing distribution network has great impact on real time system operation and planning. The aims of integration DG into all generation plants reduce the cost and greenhouse emission. In distributed power generation market micro turbine generation systems are currently attracting in order to meet customer needs. In order to investigate the performance of micro turbine generation system their efficient modelling is required. DG also helps reduce power losses and improving the system power quality .this paper presents a dynamic model of a MTG system, suitable for grid connected/islanding operation. The components of the system are built from the dynamics of each part with their interconnections .In this paper design a passive filter is designed to reduction of harmonics in the system. The MTG system is a complicated thermo dynamical system with a high speed of rotation, frequency conversion and its control strategy. In spite of several techniques to control high speed of micro turbine is not accurate and reliable due to their ant interference problem, The fuzzy logic based speed governor for a MTG system as an alternative to nominal PI or lead lag based controller. The development of fuzzy logic based speed governor including input and output membership functions with their respective members. The load variation of MTG system is performed using conventional and fuzzy logic controller.

Index Terms: distributed generation, micro turbine, permanent magnet synchronous generator, power conditioning unit, filter islanding mode, power quality.

I. INTRODUCTION

DGS have great potential to improve distribution system performance and should be encouraged .The distributed generation locate generation close to the load that is on the distribution network. Where the electric power was generated in large power plants, sent to consumers through transmission lines, and delivered to consumers through a passive distributed network in that case one of the changing paradigm is the insertion of DG into main electricity network. The integration of DG into distribution networks in recent years has transformed them from being passive to active networks [1]. The alternating current is the main power in all industries and other ascepts especially in short and mid distances .but as far distance which exceeds 500kms using the alternating current technically will face many difficulties and more costs because its difficult to control the current and all Other restrictions. Therefore recently those reasons led to building transmission lines HVDC to transmit power for long distances. The progress of DG as an important energy option in present scenario is the result of utility restructuring, technology evolutions and recent environmental policies.

DG can be scatter in different places. It can be utilized as a standby power source. Distributed generator is generally defined as a plant which is connected directly to utilities distribution network or can operate independently. If the grid power cuts off the sensitive loads (hospitals, industries) the DG can provide the emergency power for these loads. According to their capacities DGS are classified into micro, small, medium, large ranges.

They are generally considered to 100MW in capacity and are not centrally planned or dispatched. Distributed generation can be based on renewable technologies such as wind turbine, photovoltaic or recent promising non renewable technologies such as micro turbine, fuel cells and reciprocating engines.MTG is one of the best systems of DG.

The MTG has advantages of being low cost, multifueled, reliable, peak saving, and lightweight. In addition MTG offers the cogeneration system that generates heat energy as well as electrical energy. Although mtg generates the electric power using the natural gas, mit has an environmental benfit that is low nitrogen dioxide emission. Distributed generation using micro turbine is a typical and practical solution because of its environmental friendliness and high energy efficiency [2]. Various applications such as peak saving, co-generation, remote power and premium power will make its penetration wide spread.

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Once MTGS are connected the power distribution system, these generators will affect the dynamics of the system whose transient behavior can be assessed only if a detailed non linear dynamic model is used. When MTG system connected to distributed network In order to analyze the factors such as transient response, stability, power quality including harmonics, voltage regulation and protection the accurate system model is required. The electricity demand of each country increases quickly. The power generation and transmission system should also increase in order the demand. As a result the whole power system will experience more difficulty in operation and stability; such has increase active and reactive power losses, higher inherent of voltage and frequency, instability so on. Power quality refers to maintaining the near sine wave of power distribution bus voltages and currents at rated margin and frequency. it determines fitness of electric power to consumer devices .until now ,only few works are under taken on the modelling, simulation and control of MTG systems .A dynamic model for combustion gas turbine has been discussed in some previous papers[3]-[6].In these references, a combustion gas turbine dynamics, including speed, temperature, acceleration and fuel controls. A dynamic model of micro turbine generation system for isolated operation is developed in[7]-[8]. For long distances HVDC transmission line more efficient and transfer bulk power with less electric losses compared to HVAC transmission lines[9]. Hvdc transmission can improve system stability, permits the operator complete control over power flow, and facilitate the integration of wind from various resource areas [10].

MTG system improve economic condition for isolated communities means that MTG supplies power for the isolated communities Where areas are geographical obstacles and difficult to connect main power grid. The study considers the dynamic models of generator, converter ,power system and the thermodynamic model of micro turbine system modelling of micro turbine and its advanced controls for islanding operations with privileged loads are developed and presented in[11].These methods deals with unidirectional power flow between the MTG system and distribution network. In this paper a single shaft MTG system model is developed in simulink/simpower systems of the MATLAB. The developed Model considers the bidirectional power flow between the grid and MTG system. The interface controls are designed for two modes one is islanding mode and grid connected mode. The extensive simulation is carried out study the performance of the model when connected to the distribution network and connected to Hvdc system.

II.MICRO TURBINE GENERATION SYSTEM MODELING

Micro turbine designs are two types one is high speed single shaft design with compressor and turbine mounted on the shaft of permanent magnet synchronous generator and another one is split shaft design that uses a power turbine rotating at 3600 rpm and a induction generator connected via a gear box. In this type of design there is no need of power electronic interfacing. The generator generates a three phase voltage at high frequency ranging from 1500 to 4000Hz.This is converted to 50 or 60 hz voltage by Hvdc. A micro turbine can generate power in the range of 25kw to 500kw.

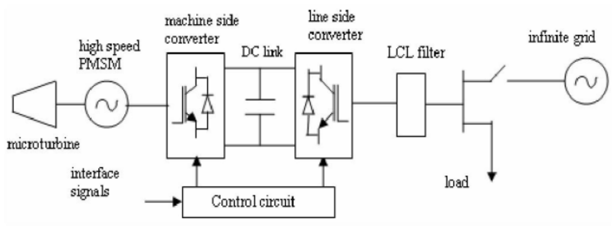

Fig. 1. Microturbine generation system (MTGS).

A. Micro turbine

The micro turbine and its controls is implemented in Matlab is shown in fig2.The model consists of fuel control, turbine dynamics and speed governor blocks. In generally MTG system consists of compressor, combustor, recuperator, turbine and generator. But in this work electro mechanical behaviour is main interest. Therefore recuperater, heat exchanger unit not included in the model as it only serves to increases the turbine efficiency. Compare the reference speed and MTG system rotor speed and then error is generated. The speed control control operates based on this speed error. It is the primary means of control for the micro turbine under part load conditions [8].

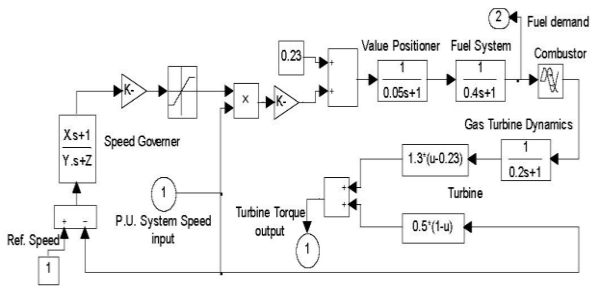

Fig2.simulink model of Micro turbine

Speed control is usually modeled by using a lead lag transfer function or by a PID controller or fuzzy PID .In This work speed controller is represented by a lead lag transfer function and fuzzy PID. The governor controls are shown in fig2 with parameters X,Y,Z and gain(k),which can be adjusted so that governor can with droop or isochronous governor. In this paper compares the results obtained for speed governor used as lead lag compensator and speed control used as fuzzy PID. Fuzzy logic controller is a rule based controller where a set of rules represents a control decision mechanism to correct the effect of certain cause used for generation system. In fuzzy logic the linguistic variables are expressed by fuzzy sets defined on their respective universe discourse to overcome the difficulties of soft controlling fuzzy logic found to be effective alternating to conventional control techniques [12]-[13]. Acceleration control can be used primarily

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during turbine start up to limit the rate of the rotor acceleration prior to reaching operating speed. The output of governor goes to low value select to produce a value for the fuel demand signal and signal from the temperature controller which is not considered here.

In MTG system first off all the compressor compresses outside air. The compressed air is heated by exhaust gas in recuperater then mixed with natural gas. The per unit value of fuel demand signal is directly proportional to per unit value of turbine output power in steady state. The valve position and flow dynamics blocks are connected in series these are represents the flow control system. The digital logic is placed instead of analog devices in governor control in order to providing time delay in fuel flow control. The fuel burnt in the combustor results in turbine torque.

B. Permanent magnet Synchronous Machine (Pmsm)

The out power of turbine is utilized for both generator and compressor. The output voltage of generator is at high frequency. A permanent magnet synchronous generator is a generator Where the excitation field provided by a permanent magnet instead of a coil. Generally rotors of machine classified as two types one is salient pole rotors and non salient pole rotors. Non salient pole rotors having better advantages compared to salient pole rotors. The model adopted for the generator is a 2 pole permanent magnet synchronous machine (PMSM)with a non salient rotor. At 1600 Hz (96000) RPM. The machine output power is 30kw and its terminal line to line voltage is 480v.In non salient pole rotor flux distribution is sinusoidal and hence gives better waveform. The model assumes that flux established by the permanent magnets in the stator is sinusoidal, which implies that electromotive forces are sinusoidal he electrical and mechanical parts of machine represented by a second order state space model. The following equations expressed in the rotor reference frame (dq-frame) are used to implement PMSM

Electrical system:

$$\frac{di_d}{dt} = \frac{1}{L_d} V_d - \frac{R}{L_d} i_d + \frac{L_q}{L_d} \mathrm{P}\, W_r\, i_q \qquad (1)$$

$$\frac{di_q}{dt} = \frac{1}{L_q} V_q - \frac{R}{L_q} i_q - \frac{L_d}{L_q} \mathrm{P}\, W_r\, i_d - \frac{\lambda P w_r}{L_q} \qquad (2)$$

$$T_e = 1.5\mathrm{P}\,(\lambda i_q + (L_d - L_q)\, i_q i_d) \qquad (3)$$

Mechanical system:

$$\frac{dw_r}{dt} = \frac{1}{j}\,(T_e - \mathrm{F}\, w_r - T_m) \qquad (4)$$

$$\frac{d\theta}{dt} = W_r \qquad (5)$$

Where,

Lq , **Ld** : q and d axis inductances
R : Resistance of the stator windings
Iq ,id : q and d axis currents
Vq,vd : q and d axis voltages
Wr : Angular velocity of the rotor
λ : Flux induced by the permanents in the stator windings
P : Number pole pairs
Te : Electromagnetic torque
J : Combined inertia of rotor and load
F : Combined viscous friction of rotor and load
θ : Rotor angular position
Tm : Shaft mechanical torque

C. POWER CONDITIONING

The simplified model of micro turbine is useful tool for studying the various operational ascepts .The performance of developed model is studied by connecting it to an isolated load. The interconnection of Micro turbine generator to load or distribution system is a critical part and it requires efficient power conditioning system. In this paper AC/DC/AC power converters are used. Semiconductor power electronic devices such as rectifiers and inverters produce harmonics in the system. The harmonics injected by micro turbine generation system are reduced by passive filter. The power conditioning is a critical component in the single shaft microturbinr design and represents significant challenges, specifically in matching turbine output to the required load. In this purpose there are different configurations are available. One is three phase diode rectifier, a voltage source inverter and filters another one is back to back voltage source inverters. In this paper uses back to back VSC this configuration allows bidirectional power flow between the converter and grid and hence no separate starting mechanism is required. In this configuration PMSM acts two modes. At starting pmsm an act motor and draw power from the grid to bring the turbine to certain speed in this mode line side converter acts as rectifier and machine side converter acts as inverter and provides ac supply to motor, this mode of operation is called motoring mode operation of pmsm. During generating mode pmsm acts as generator and power flows from MTGS to grid. In both modes of operarion grid side converter regulates the dc bus voltage while machine side converter regulates PMSM speed and displacement factor. The line side converter uses voltage/frequency control for is lading operation.

In this paper output of synchrous generator is given to rectifier this will be convert ac to dc voltage. This is step up by boost converter. In boost converter circuit IGBT device used. IGBT has higher voltage and current ratings compared to MOSFETS and BJT. IGBT has three terminals named by emitter, gate, collector. The control circuit and boost converter acts as closed loop control .because the output of boost convert is given to control circuit this is compared with constant the result is propagated through discrete PI controller.

The control circuit for generating gate signal for IGBT in boost converter is shown below.

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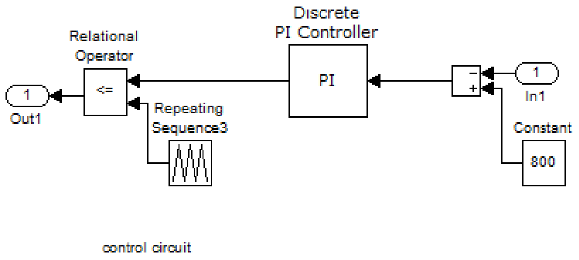

Fig 3.control circuit

2. Line side converter control

Islanding operation mode: In islanding control mode there is no grid exists. So the output voltages need to be controlled in terms of amplitude and frequency. In islanding mode alternator supplies power to the load the criteria of load affects the alternator. In this mode the amount of load supplied we can't control as it totally depends upon load demand in the covered area, but the voltage and frequency we can control. The control structure consists of output voltage controller and dc-link voltage controller. The output voltage controller will control the output voltage with a minimal influence from the shape of the load currents or load transients. A stanadard PI controller operating in the synchrously rotating coordinate system where vq kept zeroing is used. The dc voltage PI controller is acting only when the dc link is below the reference and it lowers the voltage reference of the main voltage controller in order to avoid inverter saturation.

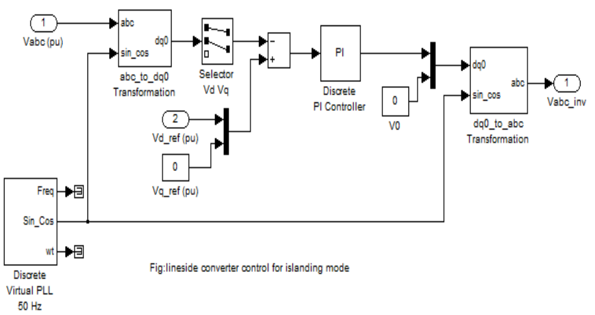

Fig.4 Line side converter control

For fast response there is direct forward connection to the voltage controller output. The control circuit for islanding mode is shown below. The IGBT inverter uses a pulse width modulation at a carrier frequency of 2KHz .The frequency regulation has been done using virtual PLL block, which is available in the sim power systems.

D. FILTER DESIGN

The primary function of the ac filter is to filter out the high frequency compents caused by inverter switching operation. However the filter also affects the low order harmonic performance of the system. Inverter used in this system is 6 pulse inverter. It generates harmonics of the order of n $\pm$1 i.e. 6 $\pm$1. The lowest harmonic is of 5^{th} order with frequency 5*50 i. e 250 hz. To get a sinusoidal output low pass passive filter is introduced in the system. The formula for cutoff frequency of filter is: $F_c = 1/2\pi\sqrt{LC}$.

Where F_c =cut off frequency
L=value of inductor in henry
C=value of capacitor in farad.

FUZZY PID:

In fuzzy PID error and change in error is given to fuzzy block and write a rules for kp,ki,kd. This is multiplied with system speed input and the resultant is given to value positioner. The input and output are transformed into linguistic variables as N: negative, Z: zero, P: positive. All the variables are considered as symmetrical triangular membership functions. The membership function would perform a mapping from the crisp values to fuzzified value.

e \ C.e	N	Z	P
N	N	N	Z
Z	N	Z	P
P	Z	P	P

e: error
c.e: change in error

error and change in error is taken has three member ship functions. These rules are applying to fuzzy block. The obtained value from fuzzy is propagating through product, integrator and derivative these are indicating kp,ki,kd with respectively.

III. SIMULATION AND RESULTS

The model used for study the performance of MTG system in islanding mode and reduction of harmonics by passive filter in MTG system is shown in fig 5.

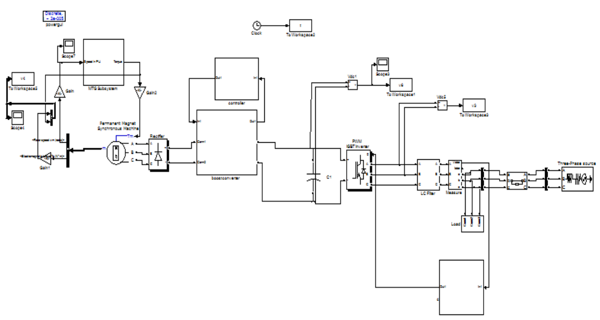

Fig5.simpower systems implementation of MTG system

The distribution network to which MTG system is connected is represented by balanced 3 phase source.

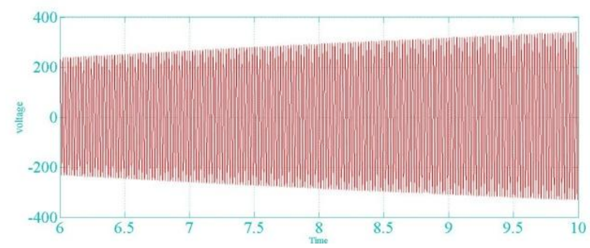

Fig 6: Voltage across load terminals

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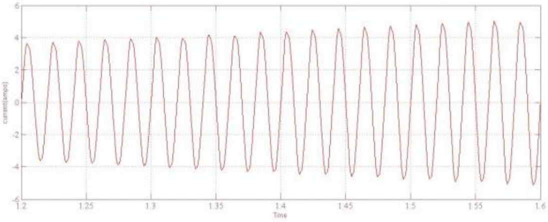

Fig7:Line current variation of the load

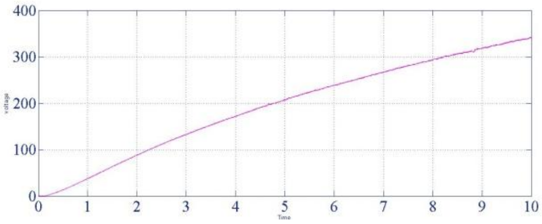

Fig 8: DC link voltage

Fig 8 shows the dc bus voltage regulated at 335 v When machine operating in islanding mode.

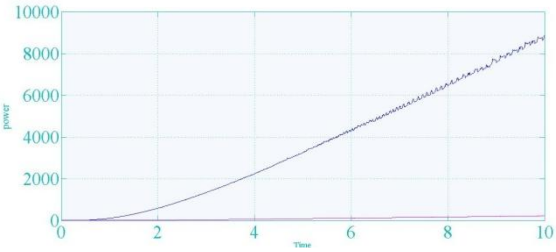

Fig9: Active And Reactive Power Variation of MTG System in islanding mode.

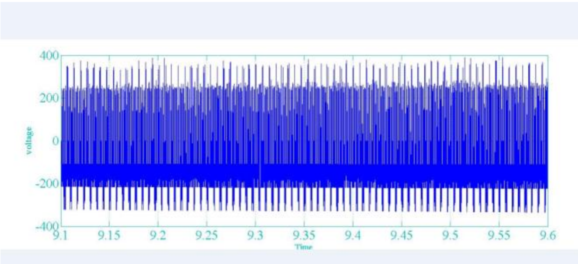

Fig 10: PMSM generating voltage before hvdc converter with speed governor used as lead lag compensator

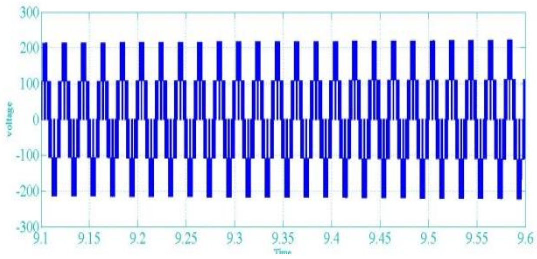

Fig 11: PMSM generating voltage after hvdc converter and before filter with speed governor used as lead lag compensator

Compare the waveforms of fig 10 and fig 11 .the total harmonic is calculated by using FFT analysis in matlab simulation. Design of interconnection of DG with load is a critical part and involves design of power conditioning system. Semiconductor power electronics devices such has rectifier and inverter introduces harmonics in the system. Harmonics reduction is one of the major issuses and needs a design of filter system. These harmonic components are reduced by passive filter.

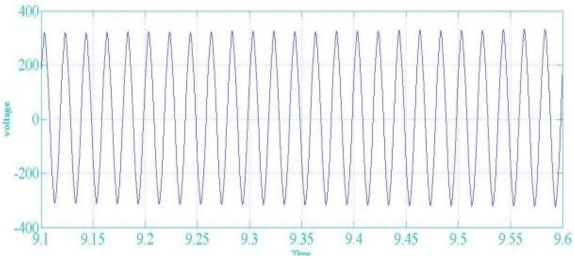

Fig 12: PMSM generating voltage after hvdc converter and after filter with speed governor used as leadlag compensator.

Compare the waveforms of fig 11 and fig 12 the THD is reduced to 58.40% to 2.45% this passive filter connection is very suitable to when MTG system is in a standalone. Whenever MTG system is connected to grid or distribution network in that case the grid system is introduces the harmonics in the system. In this case passive filter is not reduced to THD is very lesser value. In order to reducing the THD is very lesser value of MTG system when operating in a grid connected mode/islanding mode designing a active filter or hybrid filter.

The wave forms obtained for speed governor used as fuzzy pid shown below.

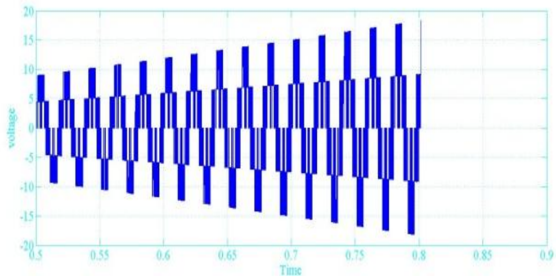

Fig 13: PMSM generating voltage after hvdc converter and before filter with speed governor used as Fuzzy PID controller.

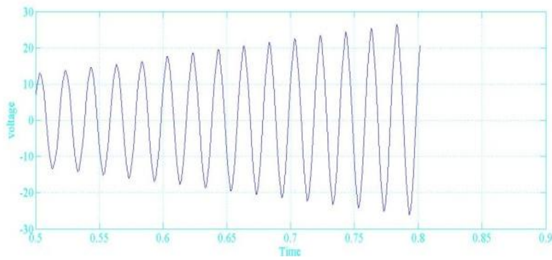

Fig 14 : PMSM generating voltage after hvdc converter and after filter with speed governor used as Fuzzy PID controller.

Compare the waveforms of fig 12 and fig 14. The THD value for fig 12 is 2.45% and THD value for fig 14 is 1.96%.this clearly indicates that fuzzy PID controller improved performance better compared to leadlag compensators.

IV. CONCLUSION

The modelling of a single shaft micro turbine generation suitable for islanding mode and reduction of harmonics in this paper. This paper replaces the conventional lead lag governor by fuzzy logic governed for a micro turbine and compares the performances of those two governors conformed that the fuzzy logic governor has a less transients. At first the mathematical model ing of micro turbine along with the control systems is given and following that the detailed simulation model of the MTG system model is developed using MATLAB'S sim power systems library. In this paper comparing the output waveforms of PMSM generating voltage before hvdc converter and after passive filter. The simulation results demonstrate the established model provides a useful tool suitable for the performerance when MTG system is connected to islanding mode. The developed model of MTG system has ability to adjust the supply as per power conditions within the MTG rating. The intentional islanding helps in providing higher reliability for the consumers.

APPENDIX

The speed governor Parameters: Gain (k)=25 x=0.4,y=0.05,z=1.

PARAMETERS OF PMSM: R_s=0.25Ω, NO of poles =2, $L_d = L_q$=0.6875mH, λ=0.0534wb.

Grid parameters: R=0.4 Q, L=2mH, 480V, 60Hz.
Load parameters: 25 kW, 480 V, 60 Hz.

REFERENCES

[1]. P.P. Barker,and R.W. Mello," Determing the impact of distributed generation on power systems: part 1-Radial distribution systems, in pro. IEEE power eng soc. summer meeting vol1-3, 2000, pp, 1645-1656.

[2] W.G. Scott," micro turbine generation for distribution system" IEEE industry applications magazine.vol 4, no.3, may-june, 1998, pp.57-62.

[3] W.I Rowen ,"simplified mathematical representations of heavy duty gas turbines," ASME trans journal of Engineering for power ,vol 105,no,pp.865-8869,oct 1983.

[4]. Working group on prime mover and energy supply models for system dynamic performance studies, "Dynamic models for combined cycleplants in power system studies "IEEE trans on power systems, vol.9,no.3 pp.1698-1708,august 1994.

[5] L.M hajagos and G.R, Berube," utility experience with gas turbine testing and modelling," in proc, IEEE PES winter meeting, vol2, jan/feb 2001, pp.671-677.

[6]. N.H annet, and A. Khan," combustion turbine dynamic model validation from tests," IEEE Tran on power systems, vol 8.no.1.pp.152-158, feb 1993.

[7] A.AI Hinai, and A, feliachi," Dynamic model of micro turbine used as a distributed generator," in pro,34 th south eastern symposium on system theory, Huntsvile, Alabama , 2002, pp, 209-213.

[8]. D.N Gaonkar,and R.N patel," modelling and simulation of micro turbine based distributed generation," in proc IEEE power India conference, new delhi , india, april 2006,pp.256-260.

[9]. Summary of impacts of the new guidelines of the International commission on NON-ionizing radiation protection on power system operation International commission on Non-Ionizing Radiation protection (INTRP).hydro-quebc-1999.

[10]. High voltage dc transmission a power electronic work house .N.G Ingrain IEEE spectrum, april 1996.The merits of HVDC underground power transsion for metro poltian.

[11] G Bertani, c.Boosi, F fornari, S.Massucco, S.spelta and F. Tivegna A micro turbine generation system for islanding operation in proc. IEEE power systems conference and exposition, 2004, pp.360-365.

[12] U.yolac and T yalcinoz "comparsion of fuzzy logic and PID controller for TCSC using matlab"39th IEEE international conference on power engineering vol.1 ,2004.pp .438-442.

[13]. B Anand and Ebenzer jeyakumar "fuzzy logic based load frequency control of hydro thermal system with non linearity " International journals of Electrical and power engineering ,vol .3 ISSUE 2 2009 ,pp.112-118.