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INTEGRATION OF PHOTOVOLTAIC AND A MICRO-TURBINE WITH DG SYSTEMS IN REMOTE AREAS USING INCREMENTAL CONDUCTANCE

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ABSTRACT- Electricity demand is increasing rapidly on a daily basis causing limitations in power supply at remote areas, this is where DG comes into picture to lower the cost of power purchased from other states. In this paper we use the IC technique, it is used to track the maximum power point of the PV source. MPPT can minimize the system cost and maximize the array efficiency. This paper discusses the integration of two Renewable energy sources for power generation at remote areas. This research was aimed to explore the performance of a maximum power point tracking system which implements Incremental Conductance (IC) method. The IC algorithm was designed to control the duty cycle of Buck Boost converter and to ensure the MPPT work at its maximum efficiency. Utility side consumers are in the remote areas who are not linked by the central electrical grid network, hybrid systems such as Photovoltaic/Microturbine have been considered as the most reliable, desired and attractive unconventional source of power supply. Based on the concept of a parallel hybrid configuration the system is designed. Here analysis and simulation of micro turbine/photovoltaic and micro turbine/fuel cell hybrid system is done using Matlab/Simulink model.

Keywords- Micro-grid, photovoltaic, micro-turbine, IC alogaritham, hybrid distributed generation, Simulation.

INTRODUCTION

Electricity demand is increasing rapidly on a daily basis causing limitations in power supply at remote areas, this is where DG comes into picture to lower the cost of power purchased from other states. Micro turbines are one of the most promising of the renewable electric generation technologies for applications today Most of the countries of the world are, looking towards natural resources, such as solar energy, wind energy, ocean energy, and geo-thermal energy etc.

A microgrid distributed generation system based on direct current bus has been considered comprising of PV power generation unit, micro turbine power generation unit, DC-DC converter and inverter unit There is a considerable importance, research work and subsidy in this field. This worldwide interest is recognized to a various aspects such as search for new energy sources due to heavy pressure on conventional fuels, simplicity, cleanliness, and direct conversion in to electricity [1] Electricity is one of the most significant energy sources for profitable activities. The fiscal growth of a country be influenced by on its efficient supply. With the industrialization growth, the requirement of electric power turns out to be growing, which is desired to consume extra fossil fuels and sources the flagging environment difficult. In the view of environment safe and save the inadequate fossil fuels, it is essential to cultivate and usage of smoke free energy. PV power generation is a noble approach to make use of renewable energy. Nevertheless, the action of PV array is unsteady as there is instability of radiation and temperature, and hence it is compulsory to combined work with governable power generation unit to enhance the stability of the entire system. [2].

Modelling of Microturbine Generator

In this section a model for dynamic analysis of a Microturbine generation system is developed. In order to model a Microturbine system, four major parts are considered. They are high speed gas turbine, high speed permanent magnet generator, power conditioning unit which itself consist of rectifier and inverter and the final part is load connected to Microturbine terminal

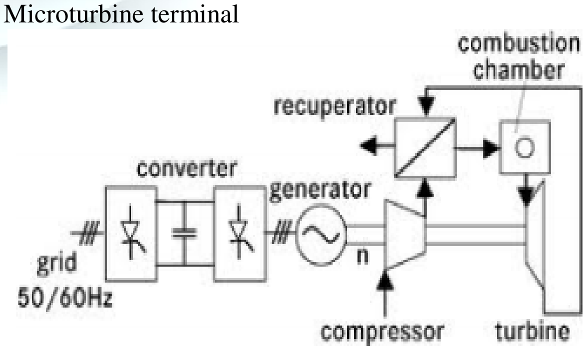

Fig 1. Microturbine Generator System.

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B. Control Functions of the Microturbine

The control functions of the Microturbine are speed control acting under part load conditions, temperature control acting as an output power limit, and acceleration control to prevent over speeding. The output of these control function blocks are all inputs to a least value gate(LVG), whose output is the lowest of the three inputs and results in the least amount of fuel to the compressor-turbine as shown in the Figure.2

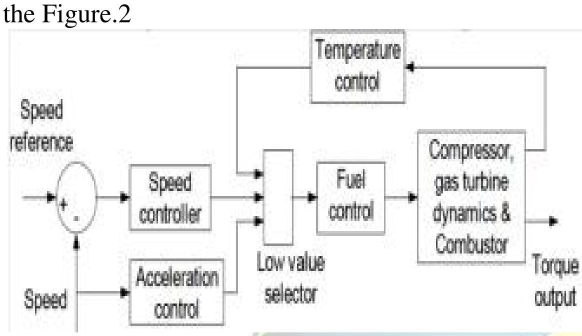

Fig 2. Control functions of Microturbine

PHOTOVOLTAIC SYSTEM MODELING

A. PV system description

Fig. 1 shows the general equation from the concept of semiconductors that mathematically define the I-V characteristic of the ideal photovoltaic cell is.

$I = I_{pv,cell} - I_d$ (1)

$I_d = I_{o,cell}\left\{exp\left({qv}/{a*k*T}\right)-1\right\}$ (2)

Where

$I_{pv,cell}$ _current produced by the incident light

I_d_Shockley diode equation

$I_{o,cell}$_reverse saturation or leakage current of the diode [A]

q_ Charge of an electron

K =Boltzmann constant

T= p-n junction temperature

a=Ideality constant of Diode.

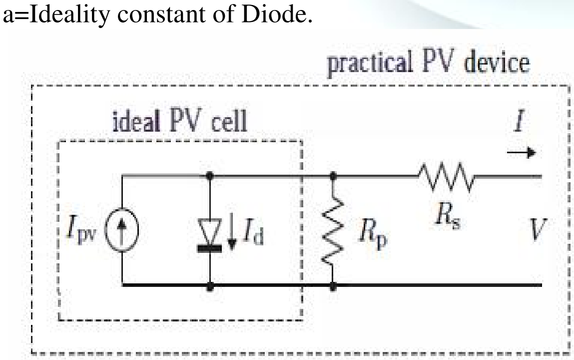

Fig 3: Practical photovoltaic cell.

Equation (2) represents elementary photovoltaic cell which does not signify the I-V characteristic of a practical photovoltaic array. Practical Photovoltaic arrays are consists of additional parameters to the general equation such series resistance & parallel resistance: [14]

$$I = I_{pv} - I_o\left\{exp\left[{(V+I*Rs)}/{(Vt*a)}\right]-1\right\} - {(V-I*Rs)}/{Rp} \quad (3)$$

Where Ipv and 10 are the PV and saturation currents of the array and Vt= (NskT)/q is the thermal voltage of the array with Ns cells joined in series. Cells which are in parallel connection to rise the current and cells which are in series give addition of voltages. If the PV array is connected in parallel the photovoltaic and saturation currents may be expressed as: Ipv=lpv,ceIlNp, lo=lo,ceIlNp. From (3) equivalent series resistance of the array (Rs) and equivalent parallel resistance(Rp).The above equation is the I-V curve seen in Fig.2., where three points are shown: short circuit(lsc), maximum power point (Vmp'!mp) and open-circuit (Voc).

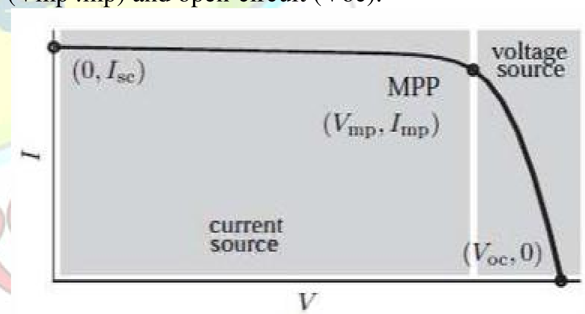

Fig.4 V& I characteristics of MPPT

The hypothesis Isc"""lpv is commonly used in photovoltaic models because the photovoltaic cel current which is generated by incident light depends on the insolation and is also the ambient temperature as per equations given:

$I = [I_{pv,n} + KI\Delta T]\,{G}/{G_n}$ (4)

where I pv,n [A] is the photo current at the standard condition, T = T - Tn (where Tn and T are the 2 . nominal and actual temperatures [K]), G [W1m] IS the insolation of the device surface, and Gn is the nominal insolation. The diode saturation current 10 and its reliance on the temperature may be stated by (5):

$$I_o = I_{o,n}\left[{T_n}/{T}\right]^3 exp\left\{\left(q*{E_g}/{a*k}\right)\left[\left({1}/{T_n}\right)-(1/T)\right]\right\} \quad (5)$$

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where E g is the semiconductor's bandgap, and lo,n is the nominal saturation current:

$$I_{o,n} = {I_{sc,n}}/{exp\left({V_{oc,n}}/{aV_{t,n}}\right) - 1} \qquad (6)$$

Vt,n is the thermal voltage of Ns series-connected cells at the nominal temperature Tn. The PV model described in the former section can be enhanced if equation (5) is substituted by:

$$I_o = I_{sc,n} + {KI\Delta T}/{exp\left(V_{oc,n} + {Kv\Delta T}/{aV_t}\right) - 1} \qquad (7)$$

This alteration targets to meet the Voc of the model with the hardware setup data for a wide range of temperatures. Eq. (6) is obtained from (5) by including the current and voltage coefficients KV and KI in the equation.

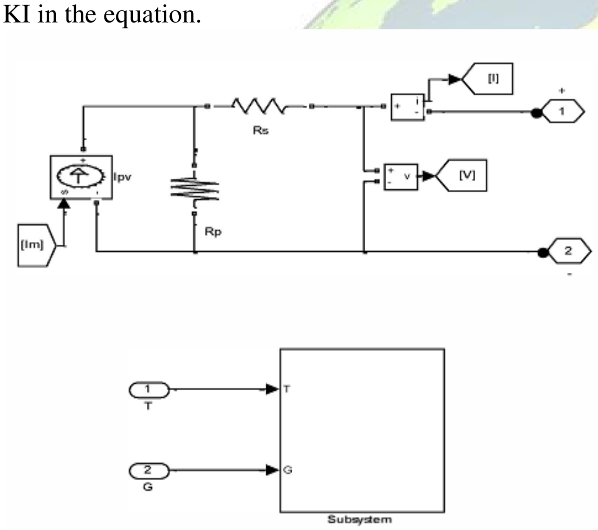

Fig.5 equivalent circuit diagram of PV system

B. Description ofthe Micro-turbine generator

The high speed PMSG generator, turbine, compressor, recuperator, and power electronics unit are the components of MTG system shown in Fig. 4

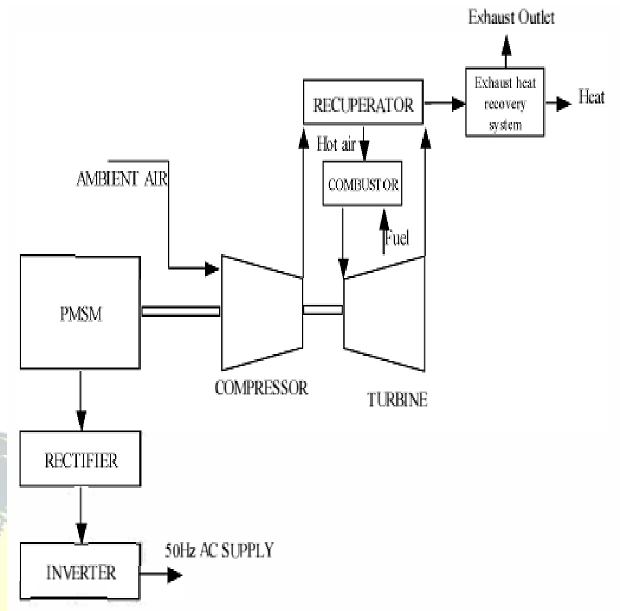

Fig 6: Single-shaft micro turbine based generation system.

The MTG systems, works on the principle of the thermodynamic cycle generally called as the Brayton cycle. System presented here, in a radial compressor the inlet air is compressed and fed to the combustor. There the air which is compressed and mixed with oil and burned to produce high pressure combustion gas.

This high pressure gas is then expanded on the turbine which is coupled to the electric generator (single shaft design). In order to increase the overall efficiency generally a microturbine will have an air to gas heat exchanger. The heat exchanger utilizes the expanded gas to heat the compressed air prior it goes to combustion chamber so this will ultimately decreases the fuel consumption during the combustion process [4].

A PMSG (Permanent Magnet Synchronous generator) is a high speed generator. This is usually used in the single shaft design. The output of PMSG is high frequency voltage (in kHz) and needed to convert this high frequency output voltage to 50Hz for normal application. Thus rectifier unit is used to convert high frequency output to DC and then converting to AC 50Hz. The presented model focuses on the slow changing aspects of the microturbine generation system, this best suits for energy management of the MTG system collectively joined with other kindss of renewable energy systems. Thus, while exhibiting the MTG for the assumed purpose, the model is functioning under regular functioning

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conditions by ignoring fast changing aspects of the MTG like start-up, stoppage, inner faults and loss etc. The heat exchanger is only serves to improve the thermal efficiency of a MTG system which is not included in the model presented [lO] [11]. [5] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of “ground-truth” reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

C. **Mathematical model for microturbine**

The fig.5 shows the MTG method presented in this is built on the generic gas turbine model [3][4]. The basic elements of the single-shaft gas turbine modeled consist of speed, temperature control and the fuel system.

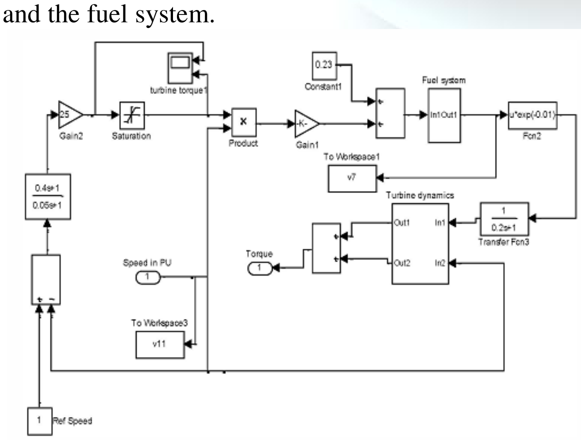

Fig.7 Mathematical model for microturbine

HYBRIDPV-MICROTURBINE SYSTEM

A 12kW PV and a 32kW MTG microgrid generation system comprising of interfacing units such as AC-DC-AC for MTG and DC-AC for PV system is shown in this paper. Though this system can be other groupings of DG, here the combination of PV generation and MTG systems are used. PV plant is more on initial investment and low on running cost, once installed there will be very low maintenance cost involved. On the other side, MTG is low on initial investment and high on running cost. Also high maintenance cost compared to PV. The presented system produces CO2 emission from the MTG is least compared to the fossil fuel generation method.

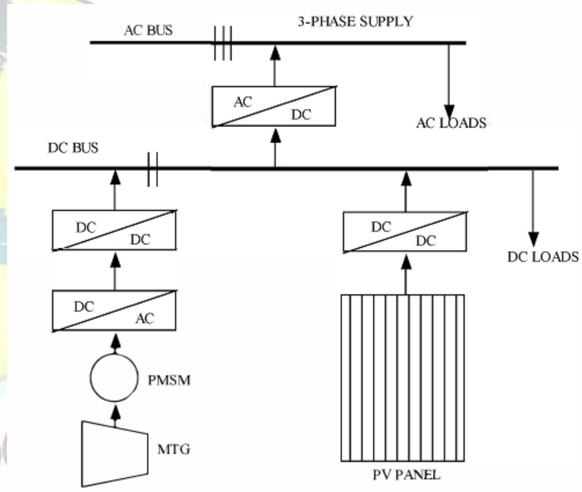

Fig.8 Block diagram of the suggested system.

INCREMENTAL CONDUCTANCE MPPT

In incremental conductance method the array terminal voltage is always adjusted according to the MPP voltage it is based on the incremental and instantaneous conductance of the PV module.

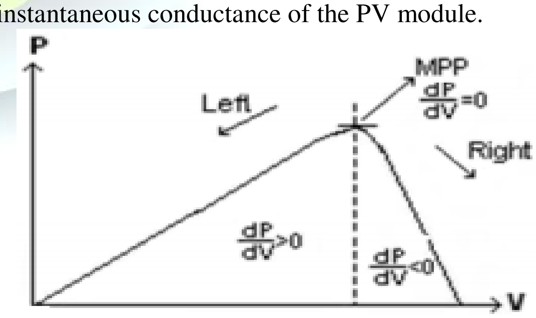

Fig-9: Basic idea of incremental conductance method on a P-V Curve of solar module

Fig-9 shows that the slope of the P-V array power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand

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side of the MPP. The basic equations of this method are as follows.

$$\frac{dI}{dv} = -\frac{1}{v} \quad At\ MPP$$
$$\frac{dI}{dv} > -\frac{1}{v} \quad Left\ of\ MPP$$
$$\frac{dI}{dv} < -\frac{1}{v} \quad right\ of\ MPP \qquad (8)$$

Where I and V are P-V array output current and voltage respectively. The left hand side of equations represents incremental conductance of P-V module and the right hand side represents the instantaneous conductance. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at the maximum power point.

INCRIMENTAL CONDUCTANCE MPPT ALGORITHM

This method exploits the assumption of the ratio of change in output conductance is equal to the negative output Conductance Instantaneous conductance. We have,

$$P = VI \qquad (9)$$

Applying the chain rule for the derivative of

$$\partial P/_{\partial V} = [\partial(VI)]/_{\partial V}$$

$$\partial P/_{\partial V} = 0 \qquad (10)$$

The above equation could be written in terms of array voltage V and array current I as

$$\partial I/\partial V = - I/V \qquad (11)$$

The MPPT regulates the PWM control signal of the dc – to – dc boost converter until the condition: $(\partial I/\partial V) + (I/V) = 0$ is satisfied.

In this method the peak power of the module lies at above 98% of its incremental conductance. The Flow chart of incremental conductance MPPT is shown below.

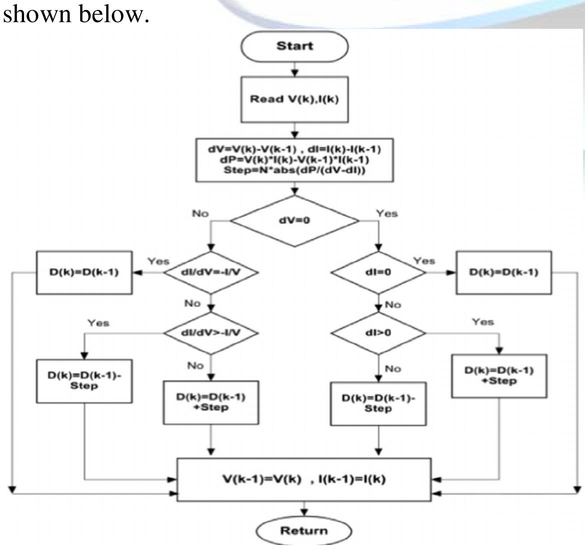

Fig. 10. Flowchart for IC MPPT of switched PV approach.

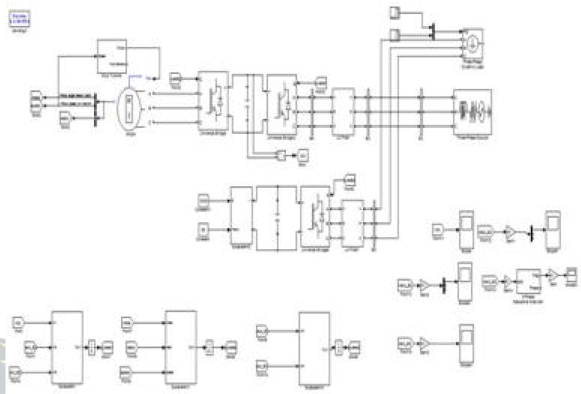

Fig.11Block diagram of simulation

SIMULATION RESULTS

The output of Microturbine is connected to pmsm and then connected to a rectifier. Thus rectified Microturbine output is integrated with fuel cell/photo voltaic system output before they are given to inverter for producing AC output, thus filtering it and giving to the dynamic load. The total Simulink model is shown in the Figure. 11

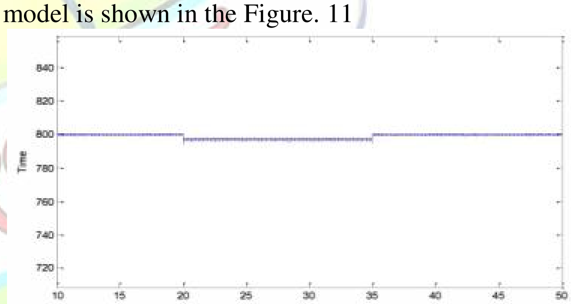

Fig.12 Part of DC output voltage

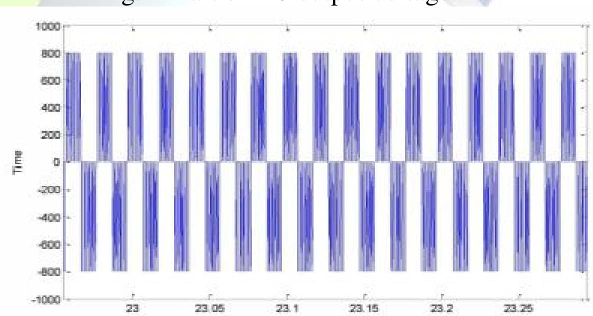

Fig. 13.Part of Inverter output voltage

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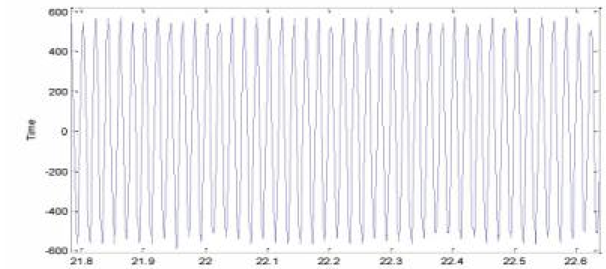

Fig. 14. Part of voltage at the load terminals

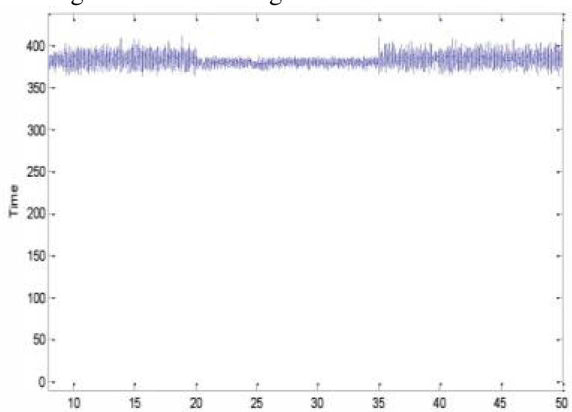

Fig. 15.Part of RMS voltage across load terminals

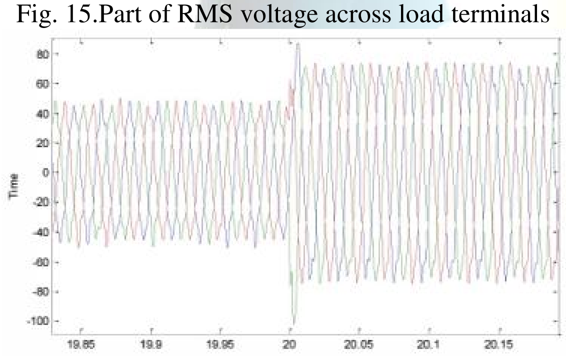

Fig. 16 Part of instantaneous load current

CONCLUSIONS

This paper compares in detail about the integration of two Hybrid systems named as Microturbine-Fuel cell system and Microturbine-photovoltaic. Both of the systems are beneficial in providing power backup facilities in remote areas. Among all the MPPT strategies, the incremental conductance technique is widely used due to the high tracking accuracy at steady state and good adaptability to the rapidly changing atmospheric conditions. The limitation of above said system is overcome by integrating MTG system. Thus load voltage variation is found to be in the acceptable range. In the incremental conductance method, the controller measures incremental changes in PV array current and voltage to predict the effect of a voltage change. This microgrid system can withstand the disturbance in the load as well as the climatic conditions, and nullifies the problems of these variations at the supply voltage. This proposed microgrid topology can be used for isolated power generation in standalone areas or remote isolated groups.

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