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Battery Energy Storage System in a Microgrid Consisting Solar PV & DFIG based Wind Energy Conservation System for St.Martin's Island

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ABSTRACT: In this study, a microgrid scheme encompassing photovoltaic panels, an energy storagesystem, and a diesel generator as a backup supply source is designed, and the optimal placement for installation is suggested. The main purpose of this microgrid is to meet the intrinsic demand without being supplied by the upstream network. Thus, the main objective in the design of the microgrid is to minimize the operational cost of microgrid's sources subject to satisfy the loads by these sources. Therefore, the considered problem in this study is to determine the optimal size and placement for generation sources simultaneously for a microgrid with the objectives of minimization of cost of generation resources along with mitigation of power losses. In order to deal with uncertainties of PV generation and load forecasting, the lognormal distribution model and Gaussian process quantile regression (GPQR) approaches are employed. In order to solve the optimization problem, the lightning attachment procedure optimization (LAPO) and artificial bee colony (ABC) methods are employed, and the results are compared. The results imply the more effectiveness and priority of the LAPO approach in comparison with ABC in convergence speed and the accuracy of solution-finding.

KEYWORDS: microgrid; optimization; lightning attachment procedure optimization (LAPO) algorithm; photovoltaic panel; uncertainty.

I. INTRODUCTION

The Generation of electrical power has been one of the top most priorities all over the world. Conventional energy sources, the common mean of electricity generation is now a matter of growing concern due to the depletion of fossil fuel reserve and environmental pollution whereas need for electricity is ever-rising. The reasons as such have played major role behind swift development in the field of Distributed Renewable Energy Resource (DRER). St. Martin's island in Bangladesh is located at 92° 19' 11.80" east longitude and 20° 37' 57.04" north latitude. The island is 17 kilometers off Taknaf, the most southern main land of Bangladesh. The island is one of the most beautiful tourist spots in Bangladesh even among the foreign visitors. Due to the island's location, establishing grid integration of electricity for population of the island will not be possible even in future. Currently the requirement of electricity is met by diesel generators which is inefficient from the perspective of cost and electricity production, both. Wind and solar based renewable energy sources are clean, feasible and moderate by cost. Hybrid energy systems incorporate blend of renewable energy sources or DRER with diesel generators - alongside converters and storages to provide grid-like power in remote territories not favored for grid network integration. An isolated grid all things considered is known as Remote Microgrid. Contextual analyses on past hybrid power system activities, constraints of current innovation and case studies on different applications are discussed by Nayar, Chem. [1]. A theory based structure or framework of microgrid is proposed by H. Wang – in regard to viable integration of renewable energy sources while considering multi stage stochastic problem to minimize overall cost [2]. A deeper look into construction strategy aiming at energy management and sizing of microgrid with storage investigated by R. Rigo-Mariani, B. Sareni & X. Roboam [3]. H.C. Chen and others have discussed about the dynamic modeling and simulation of renewable energy based hybrid power system [4]. To take care of continuing load demand through changing natural states, different renewable energy sources and storages need to be integrated with each other. Scopes of renewable power based hybrid microgrid in Bangladesh is examined by S. Nandi and H. Ghosh [5]. A hybrid system based on solar PV, wind, energy storage and diesel generator for a sample load size is attempted by Islam A.K.M. Sadrul and the most cost effective solution found for a small community of the remote island of Bangladesh, St. Martin Island. HOMER software is used to analyze and form the optimum configuration among set of combinations [6]. Studies performed over past years about integration of renewable energy sources to harvest power at DRER favorable regions in an economically rising country as Bangladesh

have not considered a concrete technical modeling or electrical design framework of hybrid microgrid based on entirely renewable energy or inclusion of conventional sources such as diesel generator was considered which are inefficient and play detrimental role of catalyst in environmental pollution, specially a naturally resourceful area both on the notes of electrical power production from renewable energy sources and landscape as St. Martin's Island. This paper proposes the design and analysis of a hybrid microgrid system for a small community of St. Martin's Island while using real case scenario data of the sources at the location throughout the year. This system incorporates an entirely renewable energy based microgrid consisting of solar PV and wind turbine farms. MATLAB/Simulink software is used to design the proposed microgrid to cater for electrical load requirement of 200 households, 20 shops and a community hospital. The system must satisfy the numerical requirement of 80 kW/day primary load with 17 kWh peak load constantly over twelve-month period.

This paper is organized as follows - first, system configuration of proposed microgrid and typical load at St. Martins Island of the community chosen are provided in Section II. Section III presents various data of renewable energy resources. Section IV & V present the Solar PV system and DFIG based wind energy conversion system of proposed microgrid. Simulation results are covered in Section VI, followed by conclusion in Section VII.

A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a college campus, hospital complex, business center, or neighborhood.

Within microgrids are one or more kinds of distributed energy (solar panels, wind turbines, combined heat & power, generators) that produce its power. In addition, many newer microgrids contain energy storage, typically from batteries. Some also now have electric vehicle charging stations.

Interconnected to nearby buildings, the microgrid provides electricity and possibly heat and cooling for its customers, delivered via sophisticated software and control systems.

First, this is a form of local energy, meaning it creates energy for nearby customers. This distinguishes microgrids from the kind of large centralized grids that have provided most of our electricity for the last century. Central grids push electricity from power plants over long distances via transmission and distribution lines. Delivering power from afar is inefficient because some of the electricity – as much as eight to fifteen percent – dissipates in transit. A microgrid overcomes this inefficiency by generating power close to those it serves; the generators are near or within the building, or in the case of solar panels, on the roof.

II. PROPOSED SYSTEM CONFIGURATION & TYPICAL LOAD AT ST. MARTIN'S ISLAND

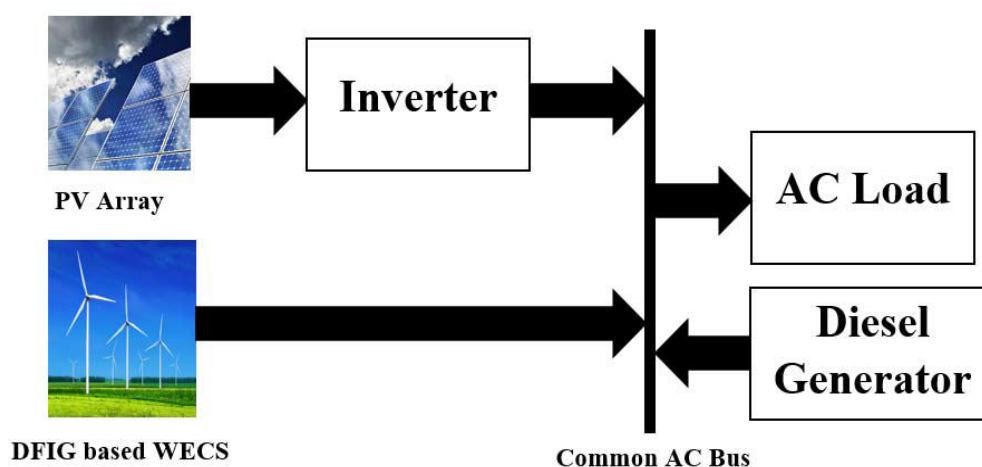


Fig. 1 Block diagram of the proposed system

The proposed microgrid which incorporates solarphotovoltaic farm and wind turbine farm. Solar photovoltaic farm will produce electricity by the means of solarinsolation and temperature whereas the wind turbine farm

will convert wind's kinetic energy into electrical power. As the sample load size considered for 200 households, 20 shops and a community hospital - 80 kW/day primary load with 17 kWh/day peak load over twelve-month period; table I below elaborates estimated load for the community

TABLE I
TYPICAL LOAD AT ST. MARTIN'S ISLAND

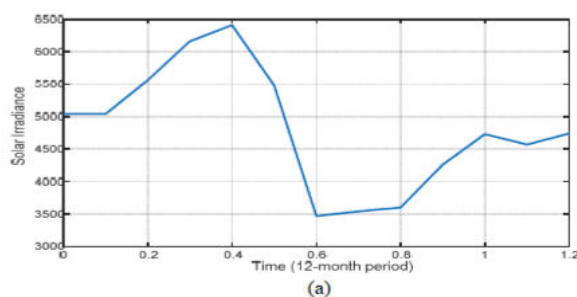
Type of Load	Number of Total Units	Per Unit Power Consumption (W)	Total Power Consumption (kW)
LED Light Bulbs	420	10	4.2
19" Color TV	10	80	0.8
Ceiling Fan	120	50	6.0
Clock Radio	60	02	0.12
Smart Phone Charger	60	10	0.6
Table Fan	20	15	0.3
Water Pump	07	400	2.8
Community Hospital			2.5
Total Load			17.32

III. RENEWABLE ENERGY RESOURCES AT ST. MARTIN'S ISLAND

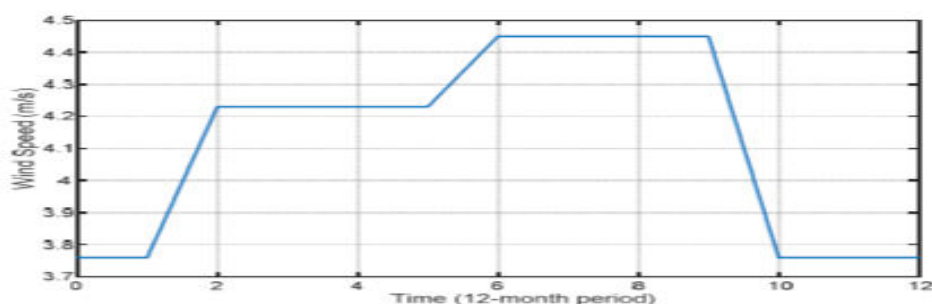
From the source of NASA's Surface Meteorology and Solar Energy website, 22-year average of solar irradiance and temperature data of St. Martin's Island can be collected by giving the input of the island's longitude and latitude values.

TABLE II
MONTHLY AVERAGE SOLAR AND WIND DATA OF ST. MARTIN'S ISLAND

Month	Average solar insolation value (KWh/m ² /day)	Average temperature value (°C)	Mean Wind Speed (m/s)
Jan	5.04	24	3.76
Feb	5.56	27	4.23
Mar	6.16	31	4.23
Apr	6.41	31	4.23
May	5.48	32	4.23
Jun	3.47	31	4.45
Jul	3.54	30	4.45
Aug	3.60	31	4.45
Sep	4.26	31	4.45
Oct	4.73	31	3.76
Nov	4.57	28	3.76
Dec	4.74	26	3.76



The mean wind speed data of St. Martin's Island over 12-month period at height of 50 m [7] and monthly average solar irradiance data has been presented in fig. 2.



III. SOLAR PV SYSTEM CONFIGURATION.

Photovoltaic cell is capable of converting energy contained in photons of light into electrical energy. PV modules are structured of PV cells which are enclosed in protective laminations. For the mentioned load requirement, 220 modules are considered in total arranged into two parallel strings which makes 110 modules per string.

TABLE III
PARAMETERS OF A SOLAR MODULE USED IN SIMULATION

Name of Parameter	Number/Ratings
Cells per module (Ncell)	60
Open circuit voltage Voc (V)	36.3
Short-circuit current Isc (A)	7.84
Voltage at maximum power point Vmp (V)	29
Current at maximum power point Imp (A)	7.35
Maximum Power (W)	213.15

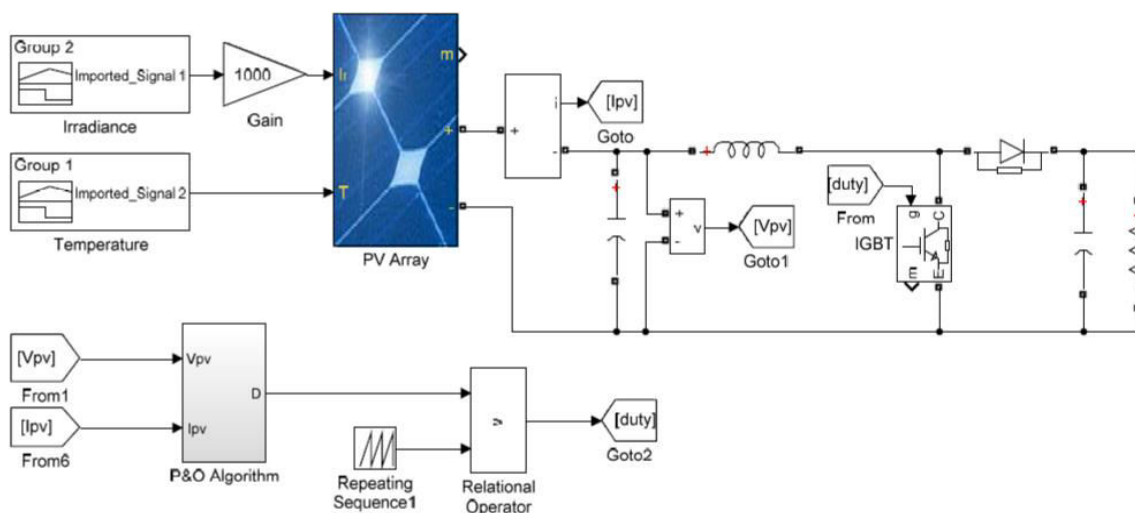


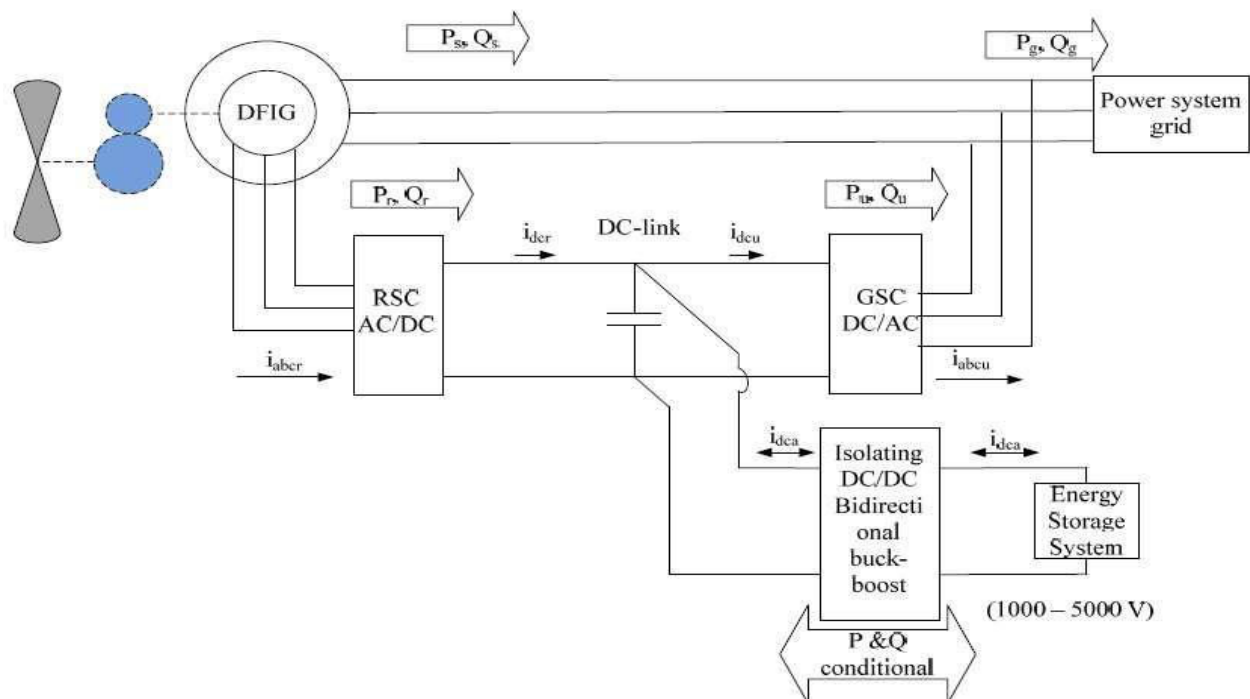
Fig. 4 PV array with boost converter

The model contains Maximum Power Point Tracker (MPPT) based on Perturb & Observe algorithm for the sake of extracting maximum power from solar farm. Algorithm chart is given below which employs controlling duty cycle of boost converter. Power of time instance is compared with power of time instance right the moment earlier relating to as an output of perturb in duty cycle in boost converter. The If perturb in duty cycle causes an increase in power compared to what was right the moment earlier, perturbation of duty cycle as happened will keep going on till a change in opposite direction takes place [8][9][10]. If a decrease in power is encountered, perturbation of duty cycle in opposite direction will take place and thus maximum power point is achieved. The modeling of solar PV farm for the sample load requirement size of the selected community is performed on MATLAB/Simulink environment which embodies variations & realistic characteristics.

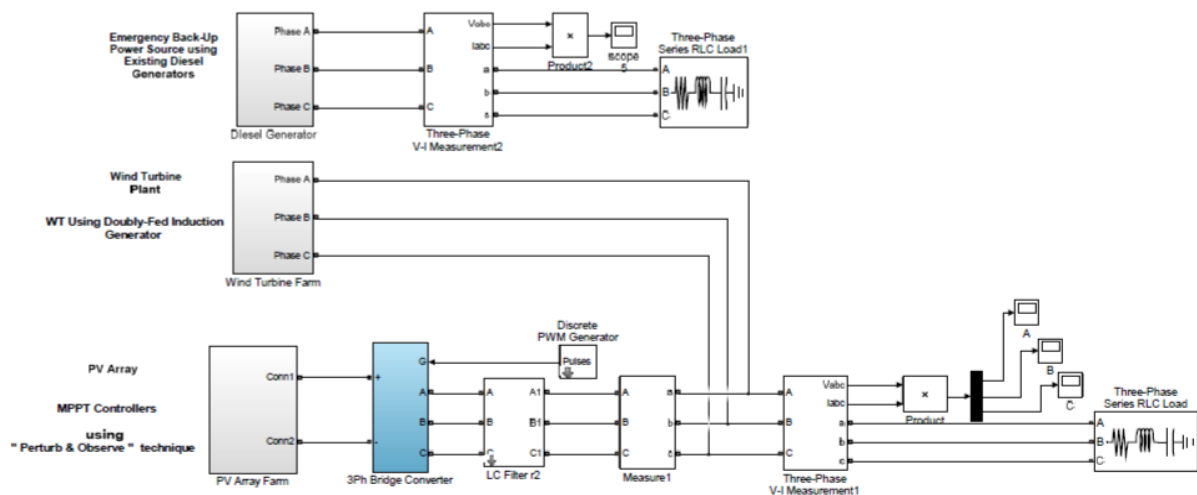
IV. DFIG BASED WIND ENERGY CONVERSION & COMBINED MICROGRID

As described in section III, St. Martin's Island is one of prominent places in Bangladesh to harvest energy from renewable energy sources. The wind speed in the island is quite favorable to implement wind turbine farms having wind turbines of rating about 3-5 kW. In modeling of wind turbine farm, here the rated capacity of wind plant is considered to be 500 kW consisting Doubly Fed Induction Generator (DFIG) based wind turbine (170 wind turbines, each rated about 3 kW as the option for onshore and off-shore both is available due to the island's geographical location). DFIG has both field magnet

windings and armature windings connected to the instrument individually outside the generator. Fig. 5 represents the simulation of wind turbine in MATLAB/Simulink environment. A Capacitor Bank is connected with three phases of wind turbine as an interconnection of capacitors either in series or parallel based on requirement, used for power factor correction & reactive power compensation. A grounding resistance is used to ground the primary side of step-up transformer via which the wind power is stepped up from 400V to 11kV and delivered to a substation, for the time being due to separately wind turbine farm modeling. To complete the entire modeling of the proposed microgrid for St. Martin's island, design contains the integration of both solar and wind generation plants combined. In this paper, a three-phase system configuration using few of the existing diesel generators has been proposed to cater for the minimum emergency load demand while the situation is acute and beyond generating power from renewable energy resources



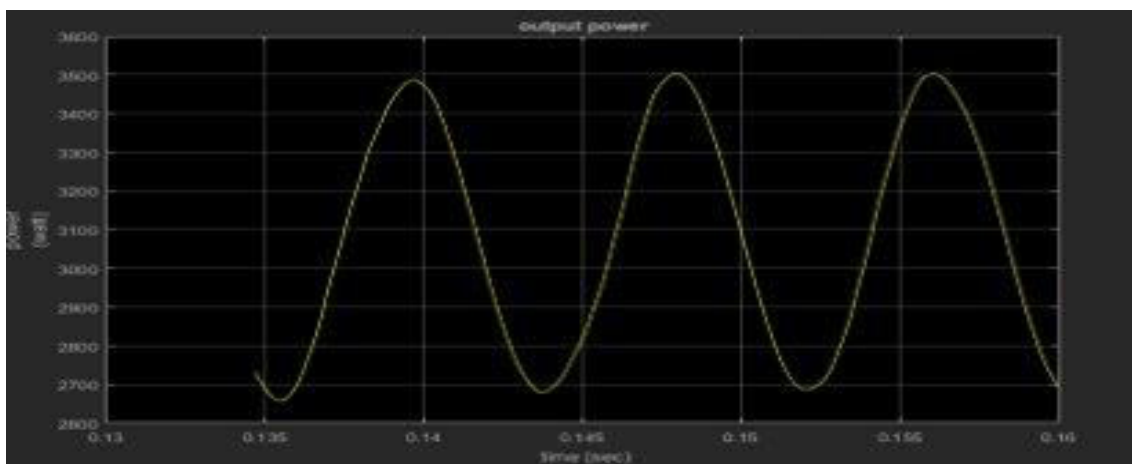
DFIG with integrated ESS in parallel with the dc link.



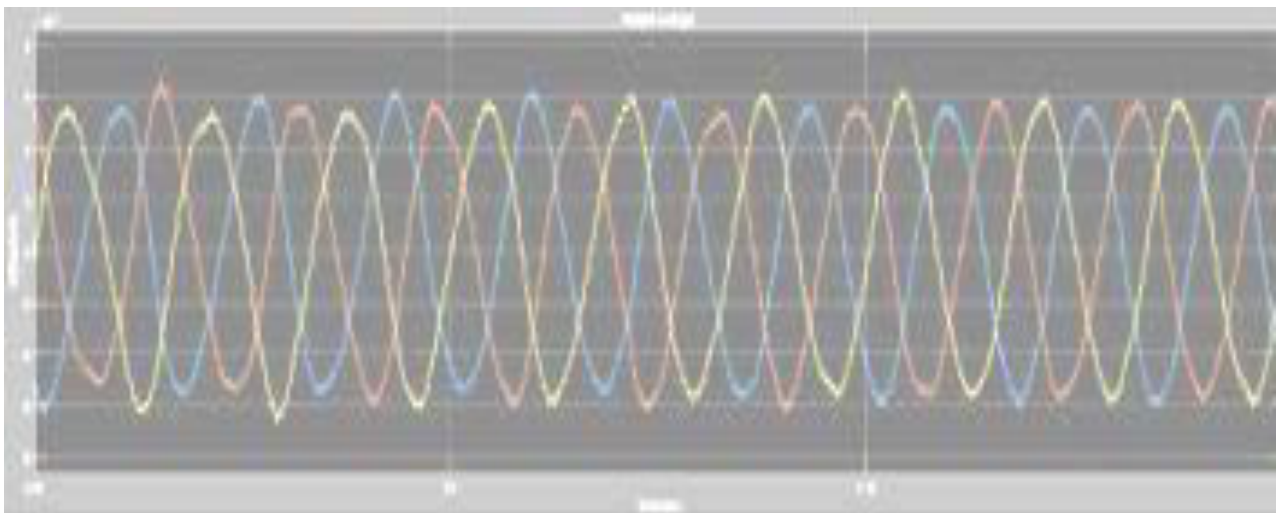
Simulation of microgrid consisting solar PV, DFIG based wind energy conversion system and backup diesel generator

V. SIMULATION RESULTS

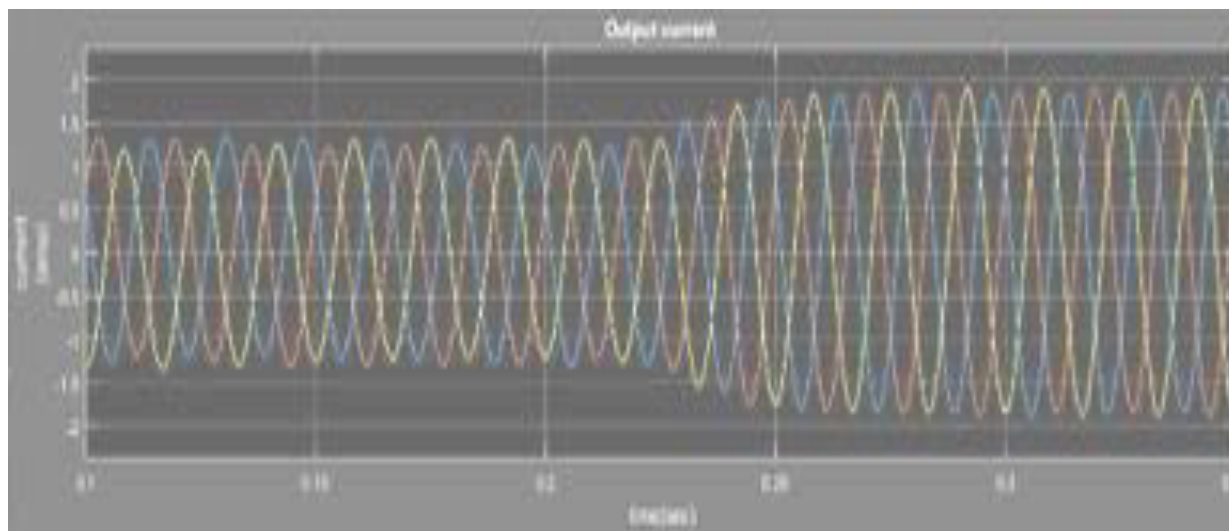
From the power output graph in fig. 7, simulation time period of 0.1 to 0.4 second (which are representing month of January to April) as the irradiance and temperature, both increase from their optimum values – the power has dropped or decreased. From simulation time period of 0.6 to 1.2 second (which are representing month of June to December), solar irradiance is gradually moving towards optimum value while temperature is not encountering significant change till November (at 1.1 and 1.2 seconds representing November and December) when temperature drops to around 25°C which is most suitable for our case. Optimum value of irradiance for the island can be understood at around 4.7 to 5.5 kW/m² as at 0.5 second (representing month of May), increase in power is identified compared to earlier, despite maximum average temperature of 32°C during 12-month period.



Output power of a microgrid



Output voltage of a microgrid



Output current of a microgrid

VI. CONCLUSION

A Modelling & Simulation of PV + DFIG based microgrids has shown better Results.

In future if we implement these kinds of Microgrids, with battery energy storage system it may helpful in reduction of DG operating hours.

In Such a way this type of Microgrid can shows better stability & Active power transformation. In fact, Redundant type of backup system available with these grids, no need of dependency on power grid. Best suited for rural areas and remote places.

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