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Improving Energy Management For Microgrid With Solar Pv And Energy Storage System

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***ABSTRACT**: Energy management from renewable energy sources has been a major challenge the world over.This Work describes Coordination of parallel connected inverters for Energy Management Improvement in a Microgrid powered by Solar PV and Battery. Models of the DGs and their dependence on meteorological parameters and renewable softwares such as Pvsyst, Retscreen and SAMNREL, SOC and Energy Demand are used to obtain annual average of daily insolation and ambient temperature for the purpose of data validation. Detailed Setup of the Microgrid and Control Configuration in MATLAB/Simpower Platform has been presented based on the validated data and simulation results from MATLAB/Simpower tool have been Analyzed. Higher DC Voltage of Solar PV is recommended for faster charging rate of the Battery during Buck mode. The Combination of different Storage system will increase the availability of storage support to Solar PV due to different dynamics and variability. Solar PV Model by the Result obtained from MATLAB/Simulink Model present a design Tool to determine the Solar PV Characteristics at all Operating Conditions.*
***INDEX TERMS:**About four key words or phrases in alphabetical order, separated by semi commas.*

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I. INTRODUCTION

In an attempt at getting the most of Solar PV Cell, MPPT is used to get the best operating point from V-I characteristics Curve. This is the location of V-I curve where voltage multiplied by current yield the highest value of power. MPPT allows an inverter to remain on the ever-moving maximum power of PV Module. Since sunlight intensity and PV Cell temperature vary considerably during the day and year, current and voltage also vary accordingly. Due to dependence on weather for Solar PV Energy sources, micro-grids with high Solar PV penetration are characterized by randomness and changeability. Solar PV generations are usually complemented by Storage System for stable and efficient power supply. Apart from storing the unused energy of Solar PV generation, storage system can assist Solar PV in meeting the grid active/reactive power demand. Employing Solar PV power sources requires complex control strategies to reduce power fluctuation and maintain stability. The control objectives for islanded micro grids and large AC power systems are similar. More specifically, for any type of AC power system: (i) generation and demand must be constantly balanced, (ii) frequency must be regulated, and (iii) costs of generation must be minimized; importantly, all of these goals must be met without violating any power output limits of the generation units (Cady et al, 2014). However, integrating DERs and controllable loads within the distribution network introduces unique challenges to micro-grid management and control which the Microgrid Energy Management system (MEMS) has to deal with. Shi et al, 2014 discussed the role of EMS in micro-grid operation and listed four essential functionalities that a micro grid EMS must support: Forecast, Optimization, Data analysis, and Human-Machine Interface (HMI). Most research work on energy management focuses on different functionalities of EMS depending on its topology as some may not be ideal to support all the functionalities. Micro grid may contain multiple power electronics blocks connected to the system in parallel operation. These converters must be controlled to satisfy several essential Microgrid requirements, including reliability, voltage regulation, and power sharing. To address these challenges, several control approaches have been proposed. The control approaches can be divided into two classes based on their architectures: centralized and decentralized. Centralized strategy increases efficient energy management through high-level communications but is inadequate for microgrids requiring high reliability and scalability. Decentralized strategy, which is usually based on droop scheme in a local controller, has improved reliability and facilitated power-sharing without need for communication between components, although mode transition flexibility and optimized energy management are restricted (Baeket al, 2017).The focus of this paper is to ensure that voltage and frequency of a single-phase AC Microgrid with inverter connected Solar PV and Battery resides within predefined threshold while preventing overcharging and undercharging. Energy Management strategy is targeted at extending the life of the Battery and maintaining good voltage and frequency regulation by Droop Control of Inverter-based energy resources and dynamic switching of the Power Electronic Interface at varying operating conditions. Stable and efficient power supply from an exclusively renewable micro grid is difficult to achieve due to random and non-dispatchable nature of renewable energy source (RES). The intermittent nature of renewable generation and load variation causes fluctuation in the micro grid network (Huang et al, 2017). This work aims to improve micro-grid energy management technique.

II. LITERATURE REVIEW

PV model was developed and verified with panel datasheet by fundamental equations and parameters from data sheet. Similarities of V-I curves for different conditions with corresponding curves in t KC200GT panel datasheet proved the validity of the developed solar panel model. In order to complement Solar Photovoltaic Generation with energy storage system, various models of energy storage system were studied. The terminal Voltage, SOC, Open Circuit Voltage and demand Current of Battery/Ultra-capacitor can be calculated by the commonly used models. According to Fuyuanet al, in 2010, properties of ultra-capacitor lie between rechargeable batteries and conventional capacitors. Charging/discharging efficiencies of ultra-capacitor is higher than that of Battery, while energy density is lower. S. Khalil and Khaled, in 2016 presented ultra-capacitor model developed from a two-stage ladder model, with RC equivalent Circuit as shown in figure 1.0.

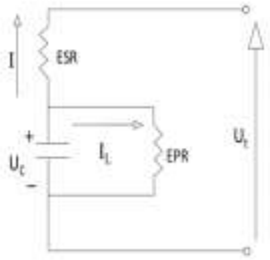


Figure 1.0: Two-stage ladder model of Ultra Capacitor

Where U_t is terminal voltage, U_{co} is open circuit voltage, I is demand current, R_S is equivalent series resistance (ESR). SOC is estimated by integrating ampere-hour as shown in equation 1.0

$$SOC = SOC_o - \int_0^T \frac{ɧI}{Q} dt \qquad [1]$$

SOC_o is Initial value ofSOC; ɧ: ampere-hour efficiency of U_{co}; Q is electric charge obtained from Q = C× U_{co}; where C is capacitance and U is voltage.

In 2006, Oureilidiset al modeled battery bank as variable DC voltage source in series with an internal resistance. According to the proposed model, the internal battery resistance depends on SOC and Temperature, while its value differs between charging and discharging periods. The dependency of SOC with open-circuit Voltage was illustrated with 2V Battery based on equation 2.0.

Write formula here; equation 2.0

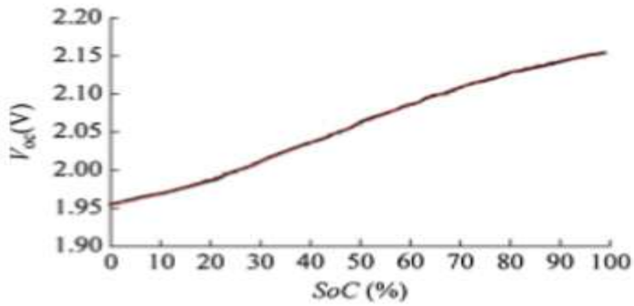


Figure 2.0: Open-Circuit Voltage characteristics

Where V_{oc} is open-circuit voltage and the parameters are equal to: $a = 1.958, b = 1.155 \times 10^{-3}$, $c = 2.946 \times 10^{-5}, d = 2.112 \times 10^{-7}$.The open-circuit voltage equation is illustrated in Figure 3.0 as given by the Battery manufacturer. Sadiq and Karthik in 2015 proposed fuzzy logic Controller for optimized energy distribution and set up Battery SOC Parameter in DC Microgrid. From the results, it was concluded that the system achieved power equilibrium, and battery SOC maintains the desired value for extension of battery life in a dc microgrid. Denholmet al. In 2017 used four PV plus Storage Configuration to examine the compromises among various PV and Storage Configurations and to quantify the impact of formation on system net value. The analysis is based on size, system operation, degree of physical and operational coupling between Storage and PV. The four system configurations studied are; independent PV and storage systems, AC-coupled PV plus storage system, DC-coupled PV and storage systems and DC tightly coupled PV and Storage systems.

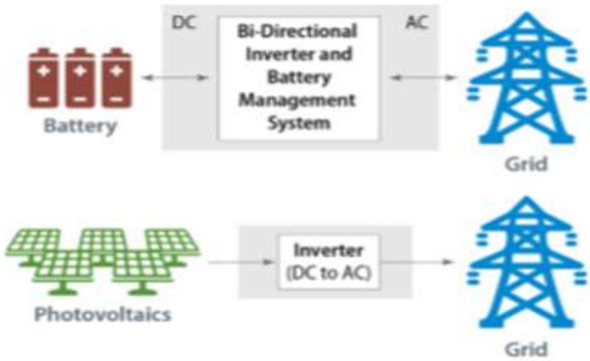


Figure 3.0: Independent PV and Storage Systems

Economic performance of solar PV plus storage configurations were evaluated in southern California by considering each system's benefit/cost (B/C) ratio. Figure 3.0 provides schematic of independent PV and storage systems. These systems are not physically co-located and do not share common components or control strategies. As a result of being autonomous, storage systems respond to total grid conditions to provide peak capacity, shift energy from off-peak to on-peak periods, and provide ancillary services. The storage can charge with any grid resource that provides low-cost energy and discharge during periods of peak demand (when energy is most expensive). Because storage is not tied to a single energy source, it can charge from whatever source of energy that has the lowest operational cost, which maximizes its value to the grid. The Storage charges from PV Energy when it is most economical.

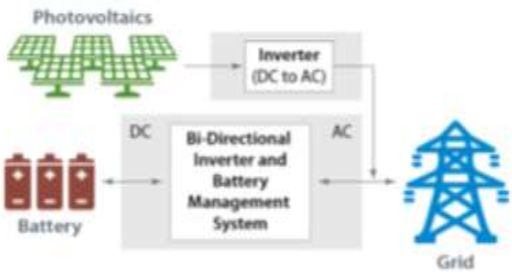


Figure 4.0: AC-coupled PV plus storage System

Figure 4.0 shows AC-coupled systems where storage and PV are in the same vicinity and share a point of common coupling on AC grid. Because the plant does not share any components, the storage can still act independently of the PV system**.**Figure 4.0b shows systems in which the PV and storage are coupled on DC side of a shared inverter. DC-coupled system (Figure 4.0b) includes a bi-directional Converter that enables the storage to charge from the grid, in addition to charging from the PV.

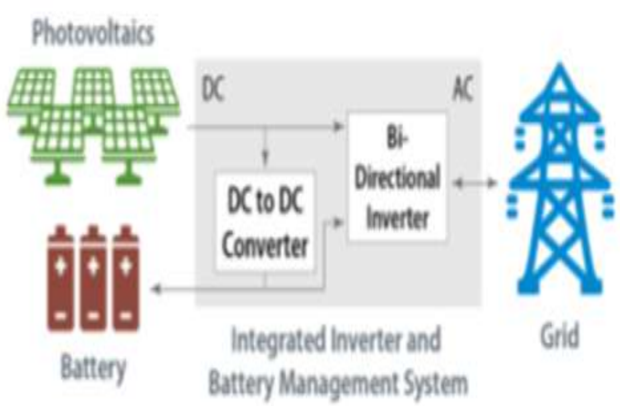


Figure 5.0: DC-Coupled PV Plus Storage Systems

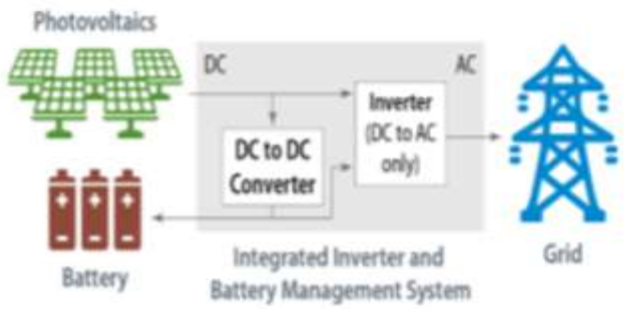


Figure 6.0: DC Tightly Coupled PV Plus Storage Systems.

DC tightly coupled system of Figure 6.0 assumes it can only store PV electricity, not grid electricity. From the analysis, Independent systems have the highest cost, because separate siting of PV and storage components increases the balance of system costs compared with the costs of AC- and DC-coupled systems. Both AC and DC-coupled systems have the potential to provide small but measurable increase in Benefit/Cost ratio compared with the independent system across a wide range of avoided-capacity costs. The findings indicate that when storage is appropriately sized, co-locating and sharing components can increase the net value of PV plus storage system. DC-coupling introduces complex set of impacts on net value, which include both increasing energy revenue by avoiding trimmed energy and decreasing energy revenue value by placing some restraints on storage dispatch associated with shared inverter. It was found that systems that charge only with PV have the highest benefit to the developer because of Investment Tax Credit. According to the author, evaluating these systems requires understanding the size of the grid connection and a more detailed analysis of non-hardware related costs including siting, permitting, and interconnection costs that can be avoided by co-locating the storage with PV. It was suggested that the configuration may not provide the highest value to the system as a whole. In addition to storing PV when other, lower-cost resources are available, the configuration incurs the risk of depending on a single source for charging the storage, thus increasing the probability that stored energy may be unavailable during periods of peak demand. Additional analysis was needed to evaluate the sensitivity of these results to alternative configurations, including tracking PV systems, different inverter loading ratios and in other parts of the country. The LCOE from a PV plus storage system will always be higher than a system without storage because storage adds costs to the system. From the investigations, it was concluded that the addition of storage also provides additional benefits that can outweigh the increase in costs. Such benefits include the value of firm capacity and the ability of a dispatch able generator to produce energy when it is most valuable.

III. METHODOLOGY

The research method adopted for the work includes:

- Review of learned journal articles.
- Analysis of Solar Resource Data from System Advisor Model (SAM).
- Modelling micro grid control systems using MATLAB/Simpower Systems toolbox.
- Model Design, verification and implementation of low Voltage microgrid consisting of inverter connected Solar Photovoltaic Energy Resource, Energy Storage and aggregate Loads

The schematic of Microgrid topology as shown in Figure 5.0 shows DES in a Microgrid with Solar PV, Lead Acid Batteries, and Ultra Capacitors. Three DC-DC Converters are used to interface DESs to a common DC Link. Each pair of DC link is connected to Bi-directional AC-DC Converter. Local loads are fed from common AC Bus of Parallel AC-DC Converters. The microgrids access Utility grid by Static Transfer Switch (STS) at the point of common coupling.

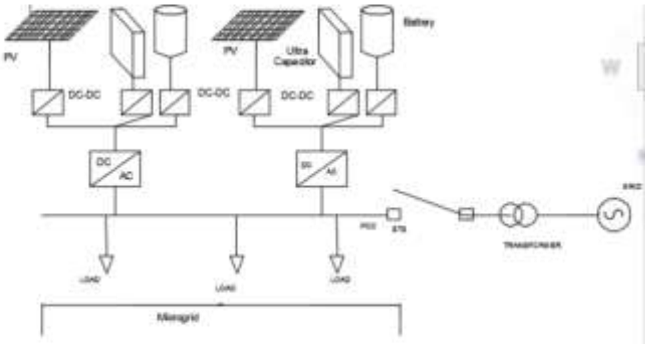


Figure 7.0 Microgrid Topology

Simulation Setup

Figure 8.0 gives the schematic setup of the Microgrid and Control Architecture in MATLAB/Simpower Platform. The microgrid configuration is an AC coupled Solar PV plus Storage System that shares a point of coupling on the AC Microgrid. The Solar PV and The Battery can operate independently as they have no Component in common. The Bi-directional converter of the Battery permits charging of the Battery from the Microgrid resources.

B. Modelling the Power System Network

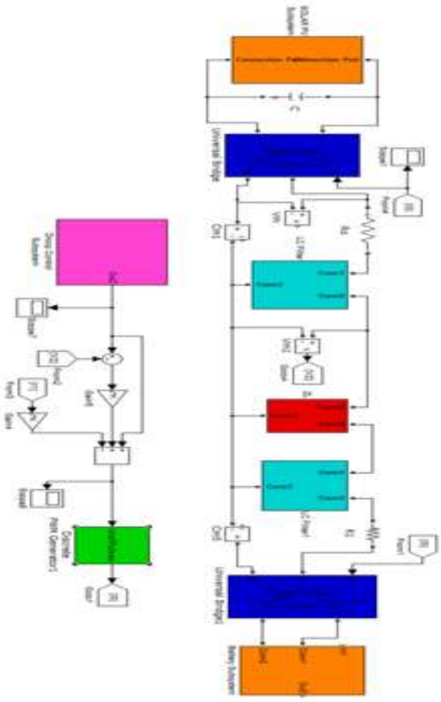


Figure 8.0: Simulation Setup

Data Collection, Analysis and Validation

Hourly Solar Resource Data is required to determine Solar PV production during 24-hours Load Cycle in Port Harcourt at Latitude 4.9^{o} and Longitude 7.0^{o}. The study choice software is System Advisor Model (SAM). SAM NREL is a performance and financial model designed to facilitate decision making for researchers involved in Renewable Energy Industry. For the study, Weather Data File for Port Harcourt is obtained through its co-ordinates (Longitude and Latitude) using SAM NREL Platform. Hour-by-Hour Solar Resources is used to calculate solar PV power output consisting of hourly Values of Solar Resources for over 10 years. Monthly Solar Resource Data are selected randomly from 1999-2017 to reduce Errors due to climatic uncertainty of a year. A total of 17,520 hourly Data for Solar Irradiance and Ambient Temperature are analysed to determine annual hourly average of Solar Irradiance and Ambient Temperature.

The procedures adopted for the analysis include:

a. Hourly Solar Resource Data for 365 days, annual average hourly Solar Irradiance and ambient temperature calculated from Monthly values of hourly Solar Resource Data.
b. Annual average of Daily Solar Insolation calculated as sum of Annual Average of hourly Solar Irradiance,
c. Annual Average Ambient Temperature calculated as 24-hour Average from Annual hourly values.
d. Validate Data collected from SAM NREL annual average of daily Insolation and Air Temperature and compare with values from two other Meteorological Data Source for the chosen Location.

Standard Approximation:

Total Number of Hours per Day = 24; Total Number of Days per Year = 365; Total Number of Months per year = 12; Number of Values for Irradiance = 24×365 = 8760; For every value of Irradiance, there is a corresponding value for Ambient Temperature; Number of Values for Ambient Temperature = 8760; Total Number of Data Process = 2×8760 = 17,520.

Table 1.0a gives hourly Solar Resource Data for Port Harcourt, while table 1.0b is the average hourly ambient temperature. The Monthly Average of Hourly Solar Irradiance and Ambient Temperature is Calculated from hourly values of each Day of the Month. A total of 24 Data per Month and 12×24 Data per Year are recorded. The resulting Data for Irradiance and Ambient Temperature are given in table 1.0 and 2.0 respectively.

Table 1.0: Monthly Average of Hourly Solar Irradiance

TIME	Jan-18	Feb-00	Mar-08	APL 2004	May-00	Jun-12	Jul-14	Aug-11	Sep-99	Oct-11	Nov-04	Dec-03	hourly Mean
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	14.10345	34.51034	7.793103	0	0	0	0	0	4.883908046
6	0	0	1.413793	55.27586	113.4138	140.5862	50.41379	59.55103	18.65517	0	0	0	38.55747126
7	0	8.724138	78.65517	164.2759	228.069	276.069	165.5862	190	134.4483	49.06897	4.137931	0	108.0862069
8	55.71875	207.7241	205.3103	323.069	393.2069	459.2759	501.931	528.2758	286.3448	174	78.41379	48.17241	225.8282407
9	175.4063	253.8621	366.9655	478.8621	527.069	386.6552	435.1724	485.7241	451.7241	295.3100	185.8621	159.8966	361.4591415
10	277.125	350.069	469.8966	607.1724	660.0345	646.2069	590.6552	589.1379	510.8621	385.7241	228.5862	256.2069	484.3063957
11	519.1875	408.4138	536.9655	837.1034	693.3103	723.9655	682.6207	655.6207	548.3448	450.3100	387.931	304.5862	516.8653261
12	359.5	456.7931	538.1724	815.5303	692.1724	780.8621	783.6207	852	585.3448	594.3100	330.4828	515.651	559.7916667
13	306.5125	417.931	481.1724	573.3793	885.2414	699.7931	773.6207	665.7241	532.8966	377.6552	267	287.3103	508.4187198
14	278.5838	368.3793	445.4138	488	620.069	658.4138	573.2069	581.3448	467.4828	334.3100	217.5790	223.1724	445.3971805
15	182.2188	264.8897	343.1379	397.2414	505.8276	529.9655	636.2414	478.6897	362.3434	186.4138	138.6897	143.7241	348.2734016
16	83.575	163.1724	227.2759	282.6897	367.6207	379.3448	506.5862	338.6552	207.5517	104	47.13793	48.65517	250.2553879
17	0	38.57143	105.0345	148.8966	224.3103	347.1379	572.6207	201.4138	84	0	0	0	118.4987685
18	0	0	0	41.44828	301.2759	134.3448	230.3103	67.82759	0	0	0	0	47.10057471
19	0	0	0	0	0	27.03448	86.86207	0	0	0	0	0	9.49137931
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0.034483	0	0	0	0	0.002873563
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
												Total	3962.707841

Table 2.0: Monthly Average Hourly Ambient Temperature

TIME	Jan-18	Feb-00	Mar-08	APL 2004	May-00	Jun-12	Jul-14	Aug-11	Sep-98	Oct-11	Nov-04	Dec-03	yearly Average TEM C
0	15.4718	17.8326	18.0047	21.5354	18.9047	21.0089	22.1047	21.5894	21.3211	20.5639	22.3086	23.2921	20.3781105
1	15.268	17.6068	18.1113	20.958	18.3484	20.7531	21.6871	21.2086	21.1055	18.8542	22.044	22.9888	20.1823184
2	15.1033	17.3965	18.0716	20.5763	18.8596	20.5954	21.3323	20.9175	21.0306	19.6059	21.8085	22.656	19.92077921
3	14.9285	17.1536	17.9085	20.1812	18.4694	20.3328	20.9819	20.6569	20.898	19.3403	21.5812	22.5817	19.55925946
4	14.782	17.0932	17.728	19.9991	18.2158	20.1561	20.7028	20.3882	20.7585	19.0988	21.4479	22.0118	19.35761159
5	15.0743	17.5898	17.8046	20.6811	18.7476	20.8171	21.1118	20.8812	20.9001	19.3025	21.6997	22.0948	19.69418178
6	15.3871	18.8794	18.2987	22.115	20.2827	21.6904	22.7975	21.8807	21.665	20.4698	22.6286	23.1755	20.80741696
7	17.5206	20.8259	16.4681	24.5785	22.7546	23.3091	24.9447	23.1855	23.5568	22.4871	24.8455	24.8305	22.68859083
8	18.6868	22.6003	20.6834	27.0274	25.0194	25.0264	26.7948	24.5008	25.3146	24.1959	26.6997	26.4141	24.41446754
9	19.4979	23.7088	21.7264	28.686	26.5996	26.3242	28.3721	25.6464	26.9207	25.7411	28.3815	27.6882	25.78925018
10	20.1718	24.4556	22.5726	29.7291	17.6884	28.996	29.5845	26.6547	28.0468	26.8864	29.5199	28.9718	26.7715094
11	20.7478	24.7455	23.1585	30.4308	18.5045	27.402	30.3891	27.3581	28.7571	27.6105	30.2568	29.6245	27.41479814
12	21.1184	24.848	23.4878	30.8101	28.9109	27.502	30.805	27.5888	29.1823	28.107	30.6108	28.9847	27.78122606
13	21.1978	25.0084	23.5581	30.7864	28.9576	27.5551	30.9884	27.5876	29.5053	28.5983	30.6789	28.8449	27.82038269
14	20.9846	24.8182	23.2786	30.6465	28.9011	27.3673	30.6511	27.3242	29.0553	28.3831	30.4588	28.4267	27.60794474
15	20.4745	24.3854	22.7271	30.1526	28.6124	27.0182	29.868	26.9232	28.4198	27.9929	29.808	28.799	27.10758019
16	19.8341	23.9047	21.999	29.4811	28.0701	26.421	29.0087	26.3477	27.579	27.2099	28.9211	28.0909	26.38902859
17	18.8779	22.9159	20.7886	28.4404	27.029	25.7166	27.9071	25.5807	26.6992	26.1976	27.7942	27.2126	25.45482664
18	17.8564	21.5859	19.3653	27.0857	25.9756	24.6098	26.4758	24.4461	25.2507	24.659	26.3328	25.9693	24.12952583
19	16.8848	20.3885	18.0659	25.3762	23.5586	25.4207	25.0952	23.8775	23.5652	23.0745	25.4768	24.9835	22.7887587
20	16.4134	19.751	17.5009	24.3448	22.4254	22.6671	24.0985	23.1832	22.5882	22.2659	24.4597	24.4827	22.0149047
21	15.8032	19.2869	17.1513	23.5303	21.8825	22.0711	23.3741	22.7061	21.9118	21.5954	23.7536	24.0366	21.40033155
22	15.5851	18.9071	17.0927	22.9848	21.0873	21.6342	22.9431	22.3142	21.5517	21.0946	23.3362	23.6526	21.007906
23	15.4619	18.5791	17.3198	22.4514	20.5171	21.2554	22.5762	21.9747	21.3874	20.6881	23.0801	23.1742	20.70595177

Annual Average hourly Solar Resource required to determine hourly Solar PV production is calculated from Table 1.0a of each monthly value for Irradiance and Ambient Temperature. The resulting table for the annual average of hourly Solar Irradiance and Ambient Temperature is given in table 3.0.

Table 3.0 Yearly Average Hourly Solar Irradiance and Ambient Temperature

Time (Hr)	Yearly Average Irradiance (W/M²)	Yearly Average Temperature (°C)	Time (Hr)	Yearly Average Irradiance (W/M²)	Average Temperature (°C)
0	0	20.3781105	12	539.7916667	27.76122606
1	0	20.10231849	13	506.4197198	27.82038269
2	0	A19.82577922	14	445.3971803	27.60794474
3	0	19.55925946	15	348.1734016	27.10758319
4	0	19.35761159	16	230.2553879	26.38902859
5	4.683908046	19.69418276	17	118.4987685	25.45492664
6	36.55747126	20.80741696	18	47.10057471	24.12952533
7	108.0862069	22.68859083	19	9.49137931	22.7887597
8	225.6202407	24.41446754	20	0	22.0149047
9	361.4591415	25.78525018	21	0.002873563	21.41933255
10	464.3063937	26.7715054	22	0	21.007906
11	516.8633261	27.41479814	23	0	20.70535177

Annual Average of daily Insolation and Mean Ambient Temperature are preferred form for Solar Data Validation. Annual average of Daily Insolation and ambient temperature are calculated from Table 4.0.

Table 4.0: Annual Average of Daily Insolation and Mean Ambient Temperature

Data Source	Daily insolation (annual average) kwh/m²/d	Mean Ambient Temperature °c
SAM NREL	3.962	23.4
RETSCREEN	3.960	26.7
PVSYST	4.000	25.3

These values are compared with values from RETSCREEN and PVSYST for validation. Solar Resource Data of PVSYST and RETSCREEN are given in Tables 4.0 and 5.0 respectively. Table 3.0 gives Annual Average of Daily Insolation and Mean Ambient Temperature for Port Harcourt at Latitude 4.9^0 and Longitude 7.0^0

Table 5.0:PVSYST Solar Resource Data page for Port Harcourt

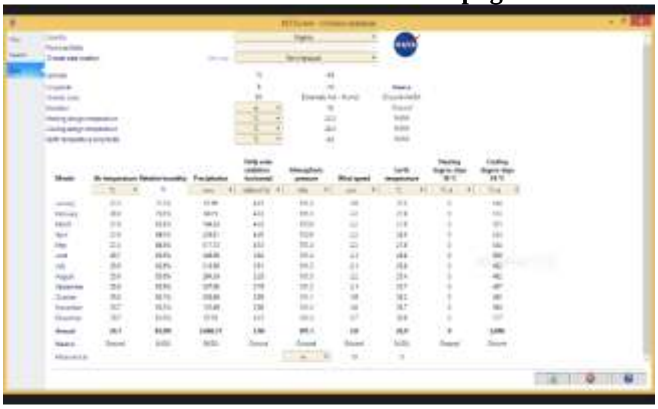
Input Data
Port Harcourt
Plane: tilt 30°, azimuth 0°

Parameters
Annual Yield 11796.8 MWh/yr
Module Cost 0.78 EUR/Wp
Technology Polycrystalline

Results
Area 66666 m2
Nominal power 10000 kW
Investment 18680035 EUR
Energy cost 0.14 EUR/kWh

	Gl. horiz. kWh/m² day	Coll. Plane kWh/m² day	System output kWh/day	System output kWh
Jan.	4.22	4.88	39205	1215340
Feb.	4.39	4.58	38523	1078633
Mar.	4.35	4.18	35096	1087961
Apr.	4.37	3.81	32003	960098
May	4.22	3.39	28458	881958
June	3.89	3.04	25575	767230
July	3.56	2.84	23867	739885
Aug.	3.36	2.85	23966	742952
Sep.	3.88	3.58	30068	902414
Oct.	3.97	4.02	33819	1048399
Nov.	4.06	4.44	37318	1119542
Dec.	4.24	4.81	40399	1252374
Year	4.04	3.85	32320	11796808

Table 6.0: RETSCREEN Solar Resource Data page for Port Harcourt



Annual Average Daily Insolation from SAM NREL in Table 4.0 agrees with the values from RETSCREEN and PVSYST, while annual Average Temperature from SAM is the lowest of all. Annual mean temperature from SAM is however less than the values of Temperature recorded during the feasible period of Solar Irradiation. Ambient Temperature ranges from 24.4^{O}C - 26.3^{O}C at 8.00am – 16.00pm. Mean temperature from SAM is however skewed by lower values of temperature outside the Range of temperature employed in the Simulation. Solar Resource Data from SAM shows slight deviation from the values of other Data source.

IV. MODELING OF MICRO GRID COMPONENT

This work uses single diode model to develop a model in MATLAB/Simulink platform, as shown in Figure 9.0.The model consists of current controlled source (Im), Series (Rs) and shunt (Rp) resisitance, with Im as a function of V, I, Io, and Ipv as shown in equation 1. Where V and I are Module Voltage and current, Io and Ipv are Diode Saturated current and photo-generated current as defined in 3.0 and 4.0 respectively (Khamis et al, 2011).

$$\mathrm{Im} = \mathrm{IpvNpp} - \mathrm{IoNpp}\left[\exp\left(\frac{\mathrm{V+Rs\,(Nss\,/Npp\,)I}}{\mathrm{VtaNss}}\right) - 1\right] \quad [3]$$

$$\mathrm{Io} = \mathrm{Isc,n} + \mathrm{Ki\Delta T}/\exp\left(\frac{\mathrm{VoC\,,n+Kv\,\Delta T}}{\mathrm{aVt}}\right) - 1 \quad [4]$$

$$\mathrm{Vt} = \mathrm{NssKT/q} \quad [5]$$

Figure 9.0: idealized Solar PV Model (Adhikari and Li, 2014).

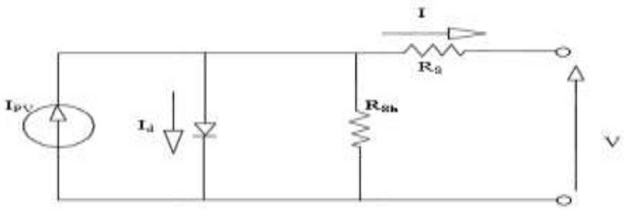


Figure 9.0: idealized Solar PV Model (Adhikari and Li, 2014).

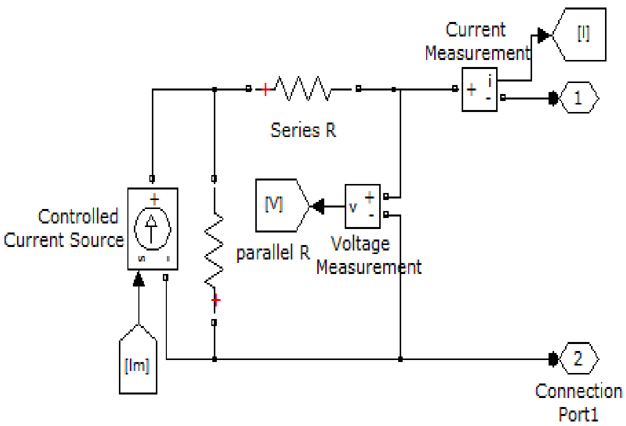


Figure 10.0: Solar PV Model in MATLAB/Simulink (Khamis et al, 2011).

Vt in equation 3.0 is module thermal voltage, Nss and Npp are Number of cells connected in series and parallel, k is Boltzmann constant ($1.3806503 \times 10^{-23}$J/K), T (Kelvin) is temperature of diode p-n junction and q ($1.60217646 \times 10^{-19}$C)is electron charge;Rs and Rp are the equivalent series and shunt resistances of the Module, respectively and a is ideality factor usually in the range of $1 \leq a \leq 1.5$.

$$\mathrm{Ipv} = (\mathrm{Ipv,n} + \mathrm{Ki}\Delta\mathrm{T})\frac{\mathrm{G}}{\mathrm{Gn}} \qquad [6]$$

WhereIpv, n is photo-generated current at 25°C and 1000 W/m^2; Ki is short circuit current/ temperature coefficient; ΔT is difference between actual and nominal temperature in Kelvin;G is irradiation on the device surface; and Gn is nominal radiation, both in W/m^2. Ipv, ncan be calculated based on equation 5.0. Solar PV Model, including building blocks in MATLAB/Simulink Platform are shown in Figure 11.0.

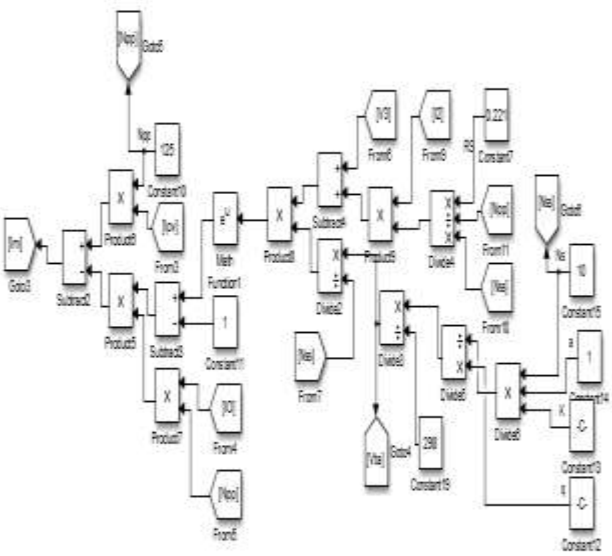


Figure 11.0: Complete Solar PV Model in MATLAB /Simulink Platform

$$Ipv,n = \frac{Rp+Rs}{Rs} Isc,n \qquad [7]$$

Sungen SGM 200P PV Module with parameters in Table 4.0 was selected from commercially available to verify the model of Figure 9.0. PV system under study has 125 parallel strings with each string having 10 series connected panels. Maximum Power for a single panel of Sungen SGM 200P at 1000 W/m^2 and 25°C (STC) is 200Watts. Maximum power at STC is $125 \times 10 \times 200 = 250$kW. It varies according to differences in Irradiance and cell Temperature.

Table 7.0: **Sungen SGM 200P PV Module Parameters at 1000 W/m^2 and 25 C**

Parameters	SGM 200P	Parameters	SGM 200P
P_{MPP}	199.882W	Kv	-0.1230V/K
V_{MPP}	27.8V	Ki	0.004A/K
I_{MPP}	7.2A	Rp	415.405 ohm
V_{OC}	34.20V	Rs	0.221 ohm
I_{SC}	7.8A	Nominal Efficiency	12.2103%

Using these fundamental equations and parameters from Poly-Si SGM 200P data sheet, PV model is simulated in MATLAB to validate the model. Combined open-circuit (Voc) and short circuit (Isc) measurement at STC are 342V and 975A. These values correspond to 34.2V and 7.8A of Table 7.0 when divided by Nss and Npprespectively. Combined characteristics of total Solar PV Modules is shown in Figure 12.0, where Short-Circuit current is plotted against Open-circuit Voltage at STC.

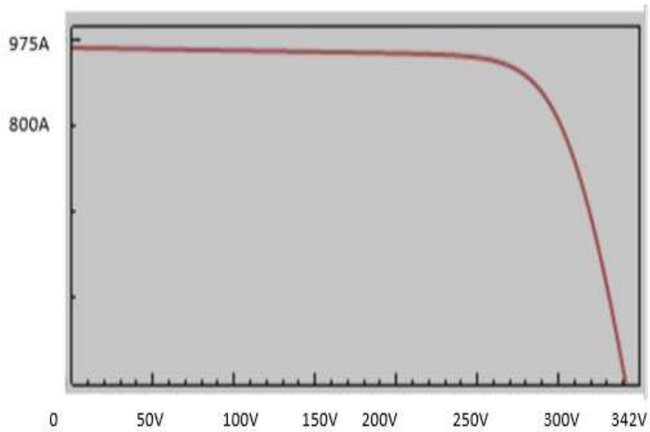


Figure 12.0 Combine characteristics of total Solar PV Modules

V. BATTERY SYSTEM MODELING

Battery bank is modeled as DC voltage source in series with an internal resistance (Oureilidiset al, 2016). The battery bank consists of 100 parallel strings with each string containing 20 batteries in series. 12V Lead Acid battery of 100Ah is chosen to provide (100× 20 × 100) 200000AH. SoC of the battery is calculated by measuring current injection from the battery and taking battery initial electrical charge:

$$SoC(t) = \frac{Q_O - \int_{t_O}^{t} I_{bat}}{Q_{bat}} \quad [8]$$

Where Q_O is battery charge at $t = t_o$, Q_{bat} is nominal battery charge and I_{bat} is battery current.
Mathematical Models and Building blocks of Solar PV Model in MATLAB/Simulink Platform are shown in Figures 13-16 respectively.
Mathematical Modeling of Solar PV

$$Io = \frac{Isc,n + Ki\,\Delta T}{\exp\left(\frac{VoC,n + Kv\,\Delta T}{aVt}\right) - 1} \quad [9]$$

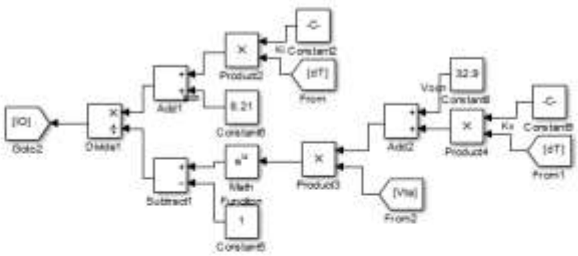


Fig 13.0: Building Block of Solar PV Model in MATLAB/Simulink

$$Ipv = (Ipv,n + Ki\Delta T)\frac{G}{Gn} \quad [10]$$

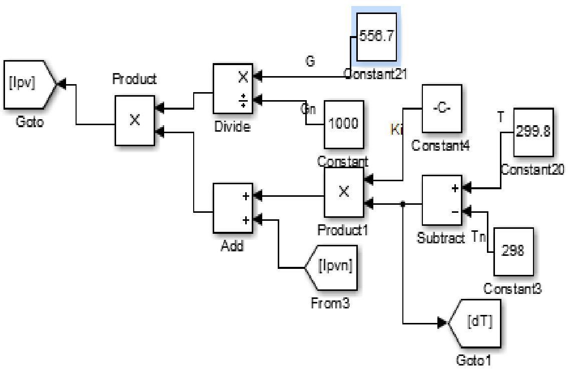


Fig 14.0: Building Block of Solar PV Model in MATLAB/Simulink

$$I_{PV,}n = \frac{R_{sh} + R_S}{R_{sh}} I_{sc} \quad [11]$$

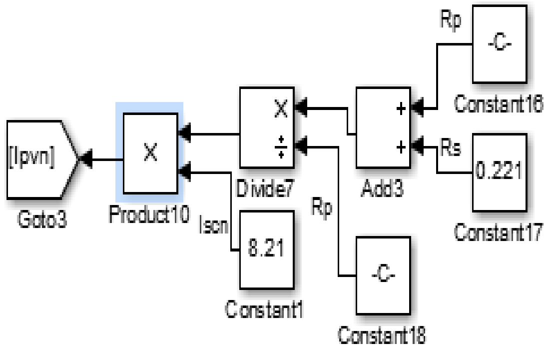


Fig 15.0: Building Block of Solar PV Model in MATLAB/Simulink

$$Im = IpvNpp - IoNpp\left[\exp\left(\frac{V + Rs\left(\frac{Nss}{Npp}\right)I}{VtaNss}\right) - 1\right] \qquad [12]$$

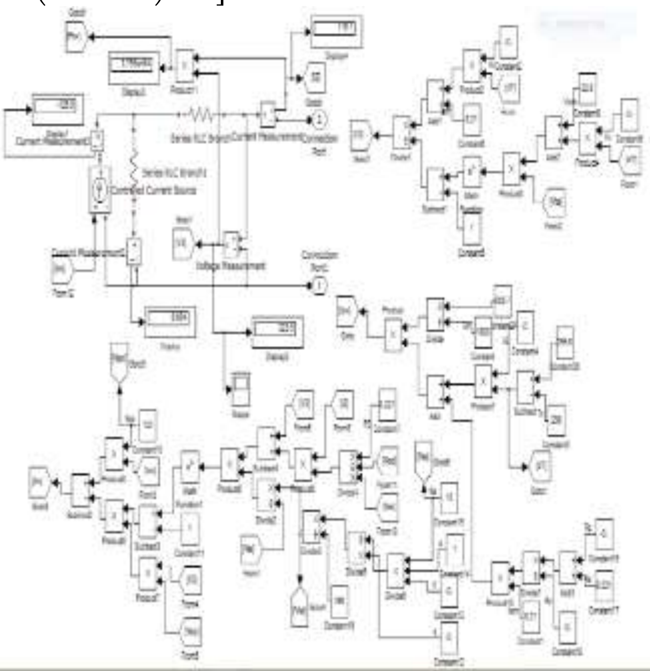


Fig 16.0: Building Block of Solar PV Model in MATLAB/Simulink

VI. RESULTS AND DISCUSSION

The Parameters of the microgrid is varied in simulation for optimal performance and improved voltage regulation. The DC voltage of Solar PV is kept constant, while the Battery voltage and the Load are varied. Three different combinations of Battery voltage (V_{Bat}) and Load are compared with the Default settings of the test system. Simulation Results, Voltage Regulations and Percentage of full Load current regarding these variations are given in table 4.5a and 4.5b respectively. Table 8 gives Load voltage and Current Measurement for different combinations of Load and Battery voltage (VB_{at}) at three distinct operating Mode. At Buck mode, Load current is derated by battery percentage Charging current. Battery voltage does not affect the Values in the Buck mode of figure 4.5a since Solar PV is the only active Source when the Battery is in charging Mode. What differentiates the different operating conditions is the percentage loading. This explains the repetition of values under the same loading conditions in Buck mode despite having different Battery Voltages. The operating conditions with values that are least deviated from nominal values are highlited as the best operating conditions.

Voltage Regulation and Percentage of full Load Current of the highlighted values of table 8.0a are compared to values obtained with the default settings using Voltage regulation of $\pm$5% as tolerable deviation from 240V.
Table 8.0 and 9.0 give respective hourly Load and energy source properties of the Microgrid at Boost and Buck Mode. Production plan of Boost mode is such that the Battery operates autonomously from 17.00hrs-7.00hrs, while from 8.00hrs-16.00hrs, both DGs operate. Only the period of feasible Solar PV production is captured in the Buck mode. Buck mode ranges from 8.00Hrs to 16.00Hrs where Solar PV is the sole provider of energy to the Microgrid, including Charging the Battery. In Figure 11.0b, only 10% of I_{PV} is utilized as battery charging current. The RMS Load Voltage and Current reduce drastically when the Battery or Solar PV operate autonomously. Frequency of Load Voltage and Current is fairly constant throughout the Load Cycle in both modes with less than 1% deviation from Nominal Value. The extent of reduction in RMS Load Voltage and Current is estimated by Load Voltage Regulation and percentage of full Load Current. Voltage regulation and percentage of full Load Current is calculated at an hour of each mode of operation.

Table 8.0 Boost Mode Properties

Time	RMS Load current(A)	RMS PV current(A)	RMS Battery current I_{Bat} (A)	Freq(Hz)	RMS Voltage(V)
0	141.6	0	141.6	49.84	66.74
1	141.6	0	141.6	49.84	66.74
2	141.6	0	141.6	49.84	66.74
3	141.6	0	141.6	49.84	66.74
4	141.6	0	141.6	49.84	66.74
5	141.6	0	141.6	49.84	66.74
6	141.6	0	141.6	49.84	66.74
7	141.6	0	141.6	49.84	66.74
8	240.5	136.1	104.3	49.67	213.6
9	240.6	136.4	104.2	49.59	214.1
10	241.3	137.1	104.2	49.59	214.7
11	240.9	136.8	104.3	49.84	213.9
12	240.9	136.7	104.2	49.67	213.6
13	240.3	136.5	104.3	49.59	214.1
14	240.5	136.2	104.3	49.59	214.7
15	240.5	136.1	104.2	49.59	213.9
16	240.3	0	104.2	49.67	68.54
17	141.6	0	141.6	49.84	67.74
18	141.6	0	141.6	49.84	67.74
19	141.6	0	141.6	49.84	67.74
20	141.6	0	141.6	49.84	67.74
21	141.6	0	141.6	49.84	67.74
22	141.6	0	141.6	49.84	67.74
23	141.6	0	141.6	49.84	67.74
			141.6	49.84	67.74

Table 3.0b Buck Mode Properties

Time	RMS Current (A)	RMS PV (I_{PV}) (A)	RMS Voltage(V)	Freq (Hz)	10% Charging Current(A)
8	153.83	168.7	78.8	49.87	16.87
9	152.01	168.9	79.1	49.84	16.89
10	152.01	168.9	79.2	49.83	16.89
11	152.92	168.8	79.1	49.72	16.89
12	152.92	168.8	79.1	49.72	16.88
13	152.83	168.7	79.1	49.72	16.88
14	152.83	168.6	79.0	49.84	16.87
15	152.01	168.9	79.1	49.84	16.86
16	152.20	168.0	78.6	49.83	16.80

VII. CONCLUSION AND RECOMMENDATION

This Work describes Coordination of parallel connected inverters for Energy Management Improvement in a Microgrid powered by Solar PV and Battery. Models of the DGs and their dependence on meteorological parameters, SOC and Energy Demand are explained. An overview of Switching Control of Power Electronic Converters has been presented, along with discussions on the realization of control algorithm for energy management improvement. Detailed Setup of the Microgrid and Control Configuration in MATLAB/Simpower Platform has been presented.TheSimulation results from MATLAB/Simpower tool have been Analyzed. Higher DC Voltage of the Solar PV is recommended for faster charging rate of the Battery during the Buck mode. The Combination of the different Storage system will increase the availability of the storage support to the Solar PV due to different dynamics and variability. Proper Load Dispatch and Deman-side management will reduce the Energy deficit during the autonomous operation of each DG and protect the microgrid component against short Circuit.

REFERENCES

[1]. Chongxin Huang, ShengxuanWeng, Dong Yue, Song Deng, Jun Xie and HuiGe."Distributive cooperative control of energy storage unit in micro grid base on multi-agent consensus method".Electronic power system Research 147 (2017) 213-223

[2]. Hala S.Khalil Khaled N. Faris, "Ultracapacitor: Modelling and Characterization for electric Vehicle Application", International journal of Engineerin Reshearch, **5** (8) 681-686 . Power electronic and enrgy conversion Department, Electronic Research institute, Dokki, Giza, Egypt, 2016.

[3]. Paul Denholm, Josh Eichman and Robert Mangolis, "Evaluating the Technical and Economics Performance of PV plus Storage Power Plant". Golden CO: National Renewable Energy Laboratory. NREL/TP-6A20-68737. 2017. WWW.nrel.gov/Publication

[4]. Stanton T. Cady, Alejandro D. Dom´ınguez-Garc´ıa and Christoforos N. Hadjicostis, "A Distributed Generation Control Architecture for Islanded AC Microgrids", December 8, 2014.International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

[5]. Wenbo Shi, Eu-Kyu Lee, Daoyuan Yao, Rui Huang, Chi-Cheng Chu and RajitGadh, "Evaluating Microgrid Management and Control with an Implementable Energy Management System" Smart Grid Energy Research Centre, University of California, Los Angeles, USA, 2014

[6]. AziahKhamis, Mathew Armstrong and MarizanSulaiman, "The impact of embebded generation due to harmonic performnace'' Third Asian international Conference on Modelling and Simulation, 2011.

Omorogiuwa Eseosa "Improving Energy Management For Microgrid With Solar Pv And Energy Storage System "American Journal of Engineering Research (AJER), vol. 7, no. 11, 2018, pp.193-205