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IMPROVEMENT OF THE EXISTING POWER NETWORK OF INDUSTRIAL ENTERPRISES THROUGH HYBRID MICROGRIDS

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Abstract

The shipbuilding industry is developing rapidly in our country and around the world. Thus, along with the construction and installation of new types of ships, the repair and periodic inspection of existing ships is also an important issue. Ship repairs are carried out at shipyards dry dock area. Preliminary research has shown that ships located in dry dock for maintenance and inspection receive electricity from external diesel generators. This is because the ships lost contact with the sea surface and can't use its own power generation network without a water-cooling system. There are shipyards with dry-dock that are not designed to meet additional power needs. Thus, the diesel generator systems used to power the ships while they are in the shipyard are accompanied by additional costs and harmful CO_2 emissions. The novelty of this article is to show the possibility of Renewable Energy Sources penetration in industrial enterprises based on their working principles and to show the new approach of RES usage. The aim in this research is to optimize the net present cost of the power supply system, highlight the amount of the CO_2 emission and to decrease it, accordingly. Our proposed project is to study the extent to which this problem can be solved using hybrid microgrids. To substantiate this idea, the following issues explored: (1) the structure of the existing electrical network of one of the shipyards and its annual energy consumption, (2) geolocation and potential solar energy sources for the area, (3) the design of a possible microgrid in island mode and its components, (4) simulation of microgrid design with HOMER software, (5) economic and environmental feasibility, (6) possibility of integration into the existing shipyard network, (7) simulation of microgrid design with HOMER Pro software.

The disadvantage of using renewable energy networks is that the energy obtained is intermittent. However, since we are proposing a hybrid microgrid in parallel with the generator, this factor will not affect the new power supply network and will lead to a more stable and environment friendly system. The proposed system will provide power to ships with different power consumption requirements, as well as power-up other electrical consumers at the plant.

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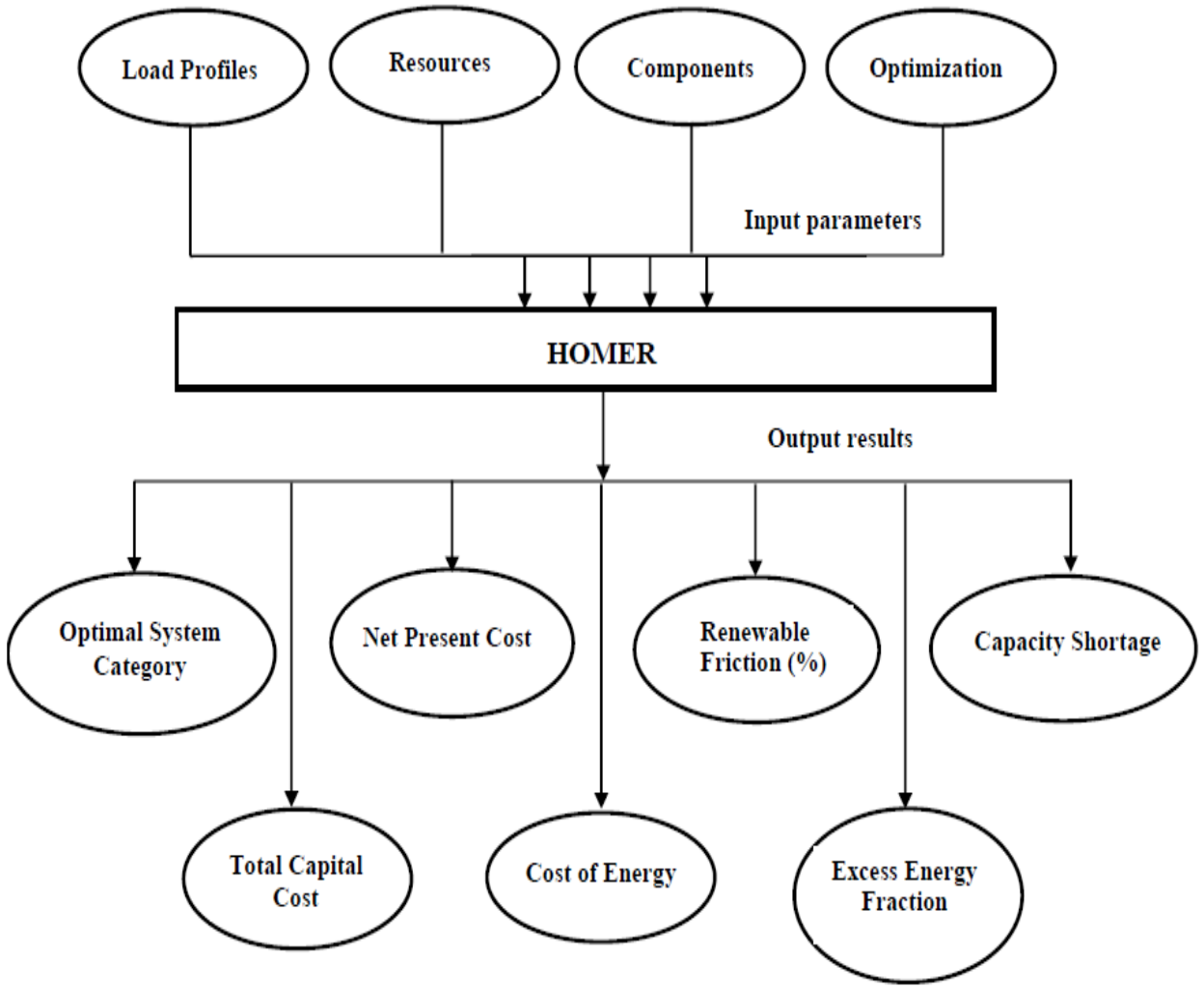
SHIPS IN A DRY-DOCK

METHODOLOGY



Simulation software architecture

Location and background information

The Caspian Sea is the world's largest inland body of water, often described as the world's largest lake or a full-fledged sea

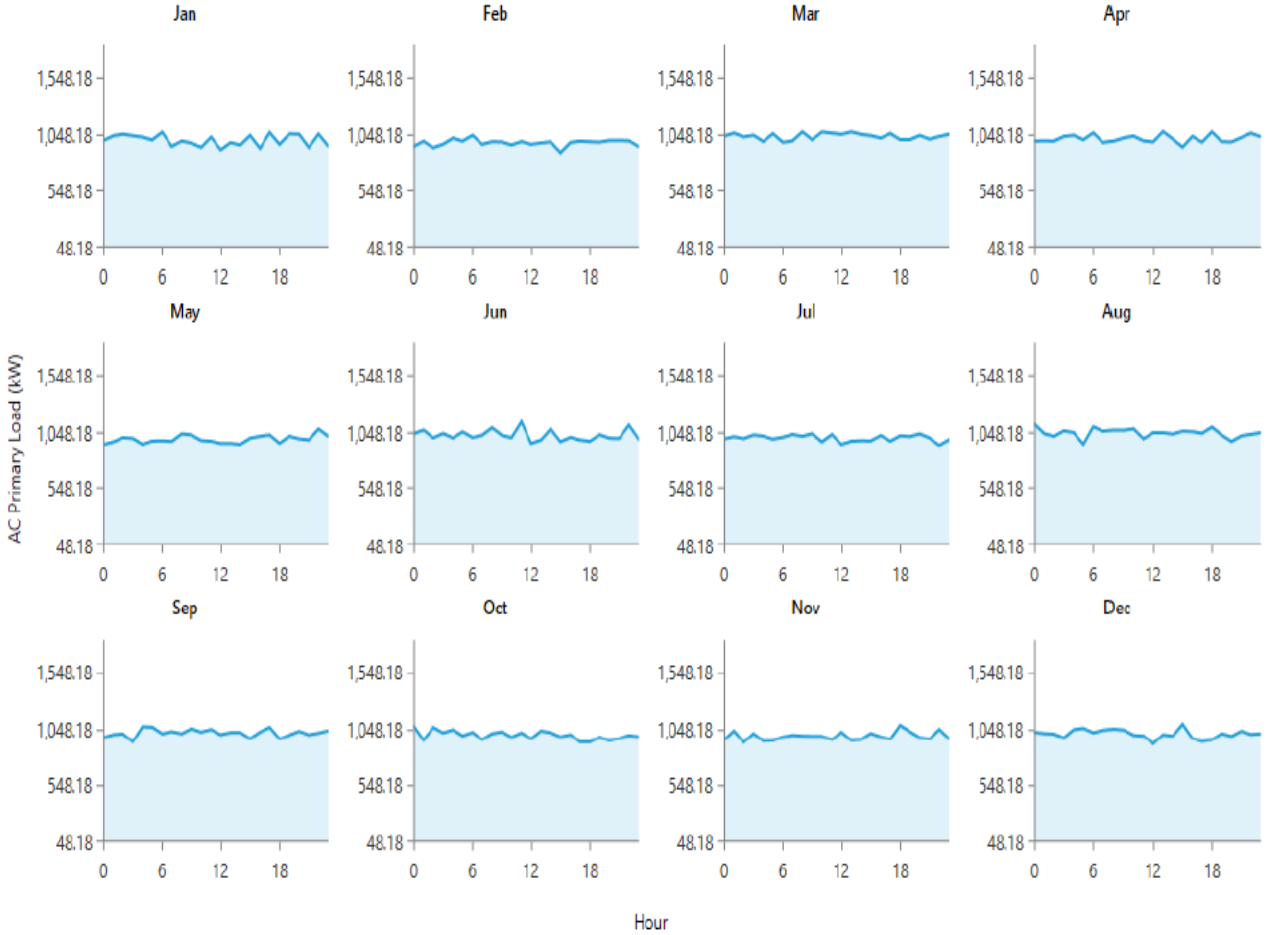
Location and background information

BAKU SHIPYARD LLC

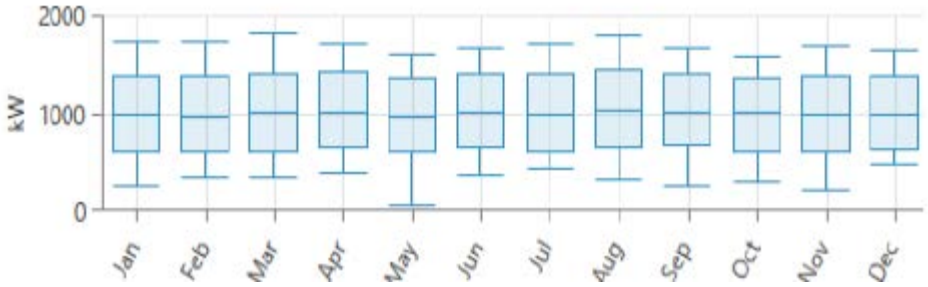
Monthly Power Demand	Active Energy (MWh)	Reactive Energy (MVARh)
January		438
February	1588	438
March	1562	664
April	1128	1.1
May	1209.3	969
June	1134.5	506.2
July	1413.2	606
August	1018	379
September	826.5	306.4
October	1279.5	478.1
November	1164.8	543.1
December	1486.7	423.1
Total	**13810.5**	**5752**

Monthly power consumption of Baku Shipyard

Location and background information

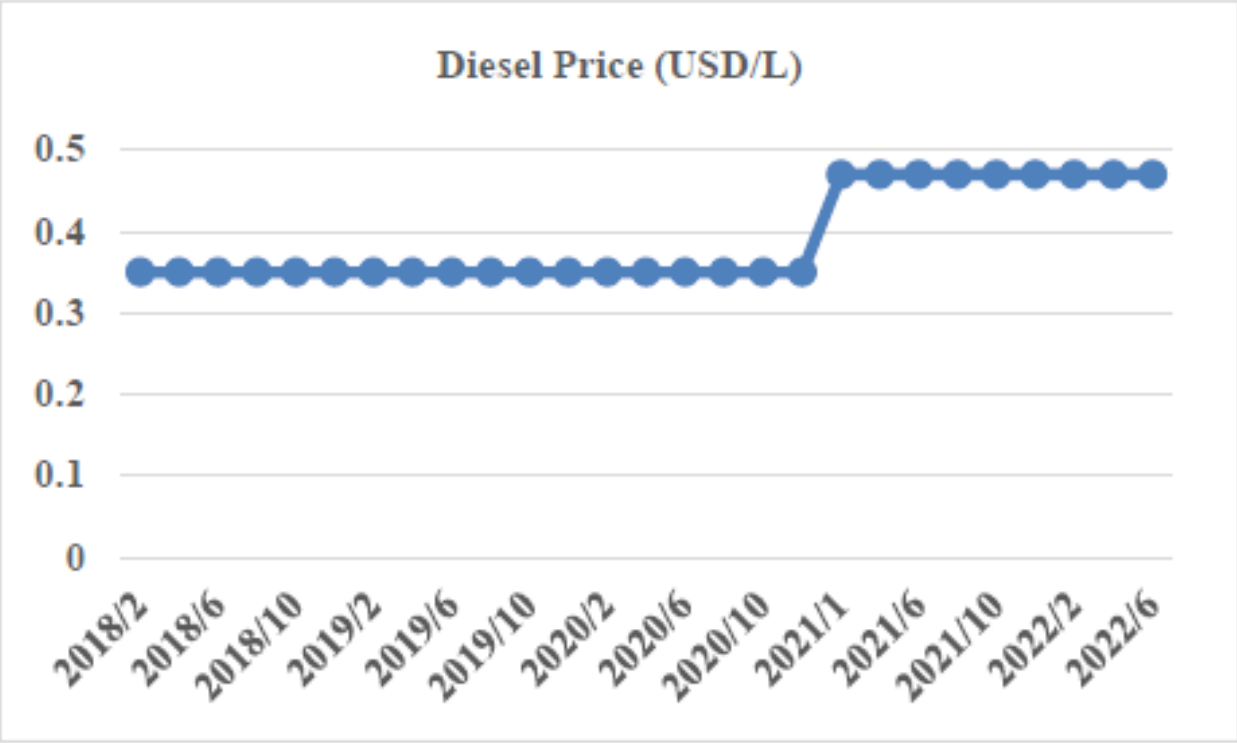


Daily Load profile of the ship in dry dock



The load is considered industrial with no major changes in profiles. Average daily energy consumption is 24000 kWh/day, with 1833 kW peak. The shipyard dry dock is occupied with the ship during 80% of the year. For the simplicity of the research, we have considered that during the entire year the dock is full.

Diesel price data



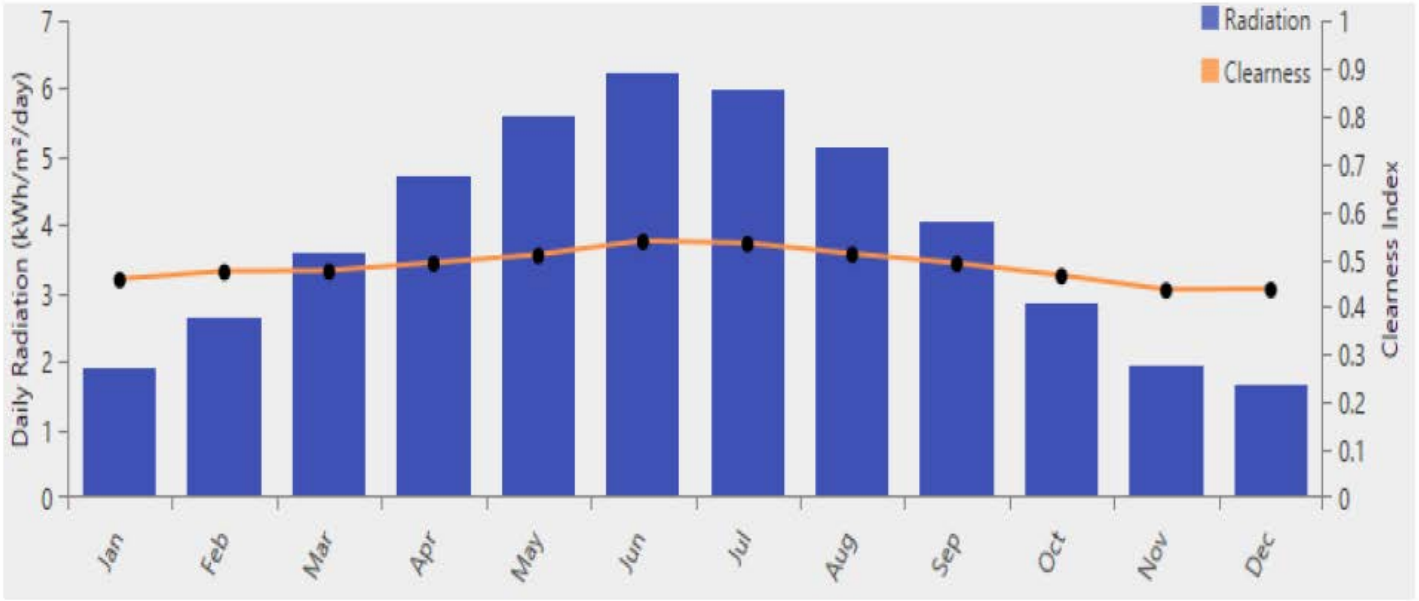
Diesel Price data variation

The diesel price in Azerbaijan has changed twice during the last 10 years. From 2013 till 2021 the price was 0.35 USD/l. In 2021 the price increased till 0.47USD/ l in order to increase the diesel quality and increase usage of renewable energy sources in country. This is regulated by Tariff Council of Azerbaijan republic and the rates will be valid till July 2022.

Solar Irradiation data

Month	Clearness Index	Daily Radiation (kWh/m2/day)
Jan	0.455	1.91
Feb	0.472	2.64
Mar	0.473	3.59
Apr	0.489	4.7
May	0.506	5.58
Jun	0.536	6.21
Jul	0.531	5.99
Aug	0.509	5.14
Sep	0.489	4.04
Oct	0.463	2.86
Nov	0.433	1.95
Dec	0.435	1.64

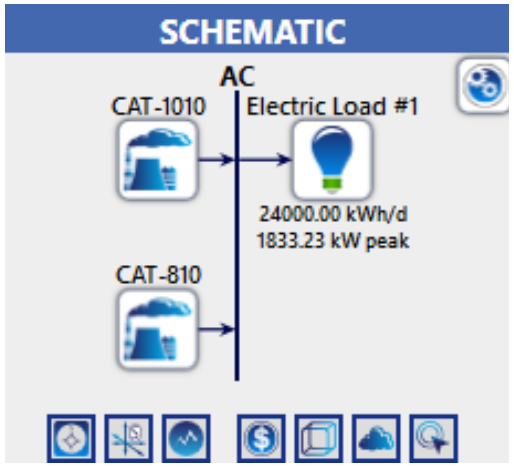
Monthly averages of Global Horizontal Irradiation



The statistic of global horizontal irradiation (GHI) is download via HOMER Software from NASA Prediction of Worldwide energy resources database. Table shows the monthly averages of the GHI for the period of 22 years (1983-2005). The annual average of GHI is 3.85 (kWh/m2/day). The value of GHI is highest in July 5.99 (kWh/m2/day), lowest in December 1.64 (kWh/m2/day)

Stand alone diesel generation

In this section the result of the simulations for the current configuration is presented. The simulation with 2 generator is done to see the initial values of CO2, fuel consumption, NPC and other economical parameters and be able to compare with the proposed solution

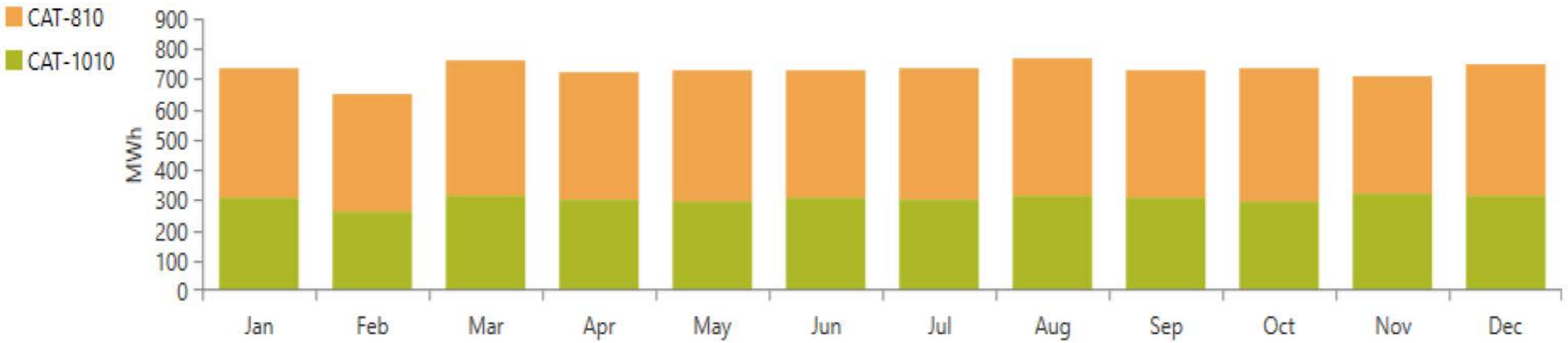


Existing system schematic diagram

Generator	Technical Parameters			
	Rated Capacity (kW)	*Model / Type*	*Fuel Consumption (l/hrs)*	*Running time (hrs/day)*
DG1	1010	CAT-1010kW-60Hz-CP	36.4	24
DG2	810	CAT-810kW-60Hz-PP	21.7	12

Generator simulation parameters

Simulation results



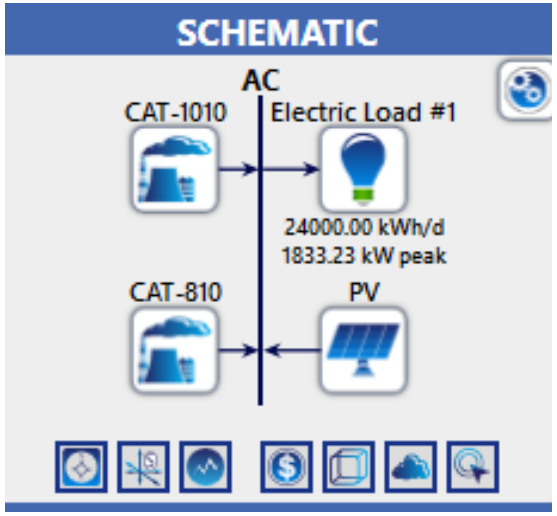
Monthly electric production

Generator	Economic characteristics					
	Capital Cost (USD)	*Replacement cost (USD)*	*O&M (USD)*	*Fuel Cost (USD)*	*NPC (USD)*	*COE (USD)*
DG1	1,050,000.00	1,570,685.86	$498.36	6,942,479.88	9,527,312.14	0.1686
DG2	1,000,000.00	466,252.50	$435.72	8,125,998.40	9,562,174.94	0.1686

Generator	Simulation Results			
	Hours of Operation (h/year)	*Electrical Production (kWh/year)*	*Fuel Consumption (l/year)*	*Specific Fuel Consumption (l/year)*
DG1	7,710	3,656,534	1,142,620	0.312
DG2	7,710	5,103,619	1,337,408	0.262

Proposed hybrid microgrid

The PV system operated in parallel with the bigger diesel generator, which is 1010kW and uses AC coupled. The electricity produced by the PV system during the day can be supplied to the AC load to decrease the output of diesel generators and reduce fuel consumption. The other generator 810kW is considered to be used only in an emergency or main generator maintenance period. For the simulation, the PV module selected is a LONGi Solar LR6-60PB model with mono-crystalline silicon solar cell type and the specifications are as follows: 305 Wp rated power, 18.7% efficiency, 0.380 coefficient of power temperature, 25 years working life and 80% derating factor

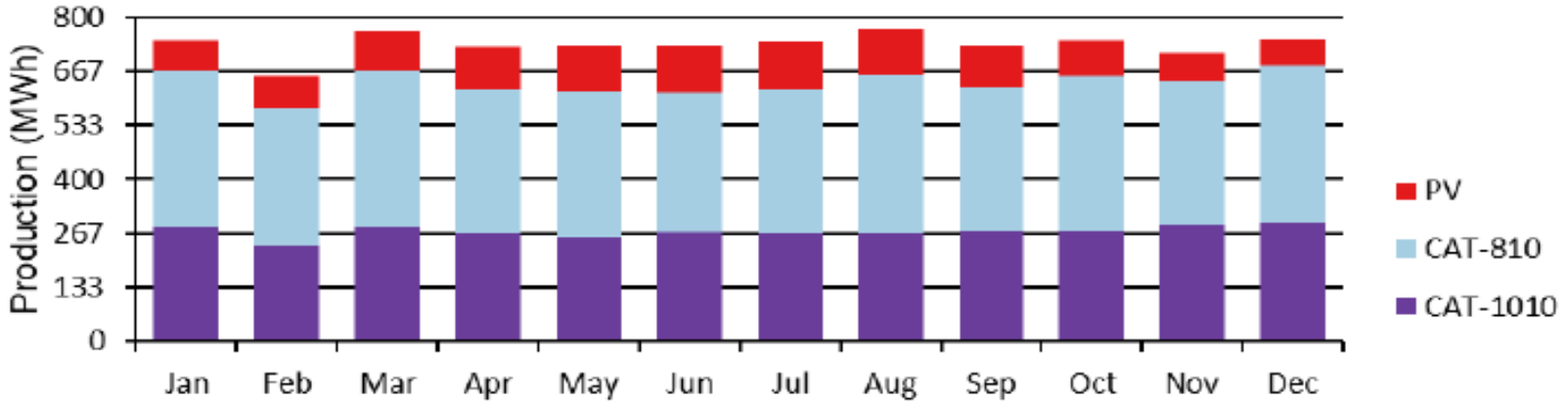


Winning system architecture

Description	Capital Cost
PV System	
Capital Cost (USD/kW)	2000
Replacement cost (USD/kW)	2000
Operation and Maintenance cost (USD/kW)/year)	20
Diesel Generator	
Capital Cost (USD/kW)	500
Replacement cost (USD/kW)	400
Operation and Maintenance cost (USD/h)	0.005

Summary of components cost for the hybrid PV/Diesel generation

Simulation results



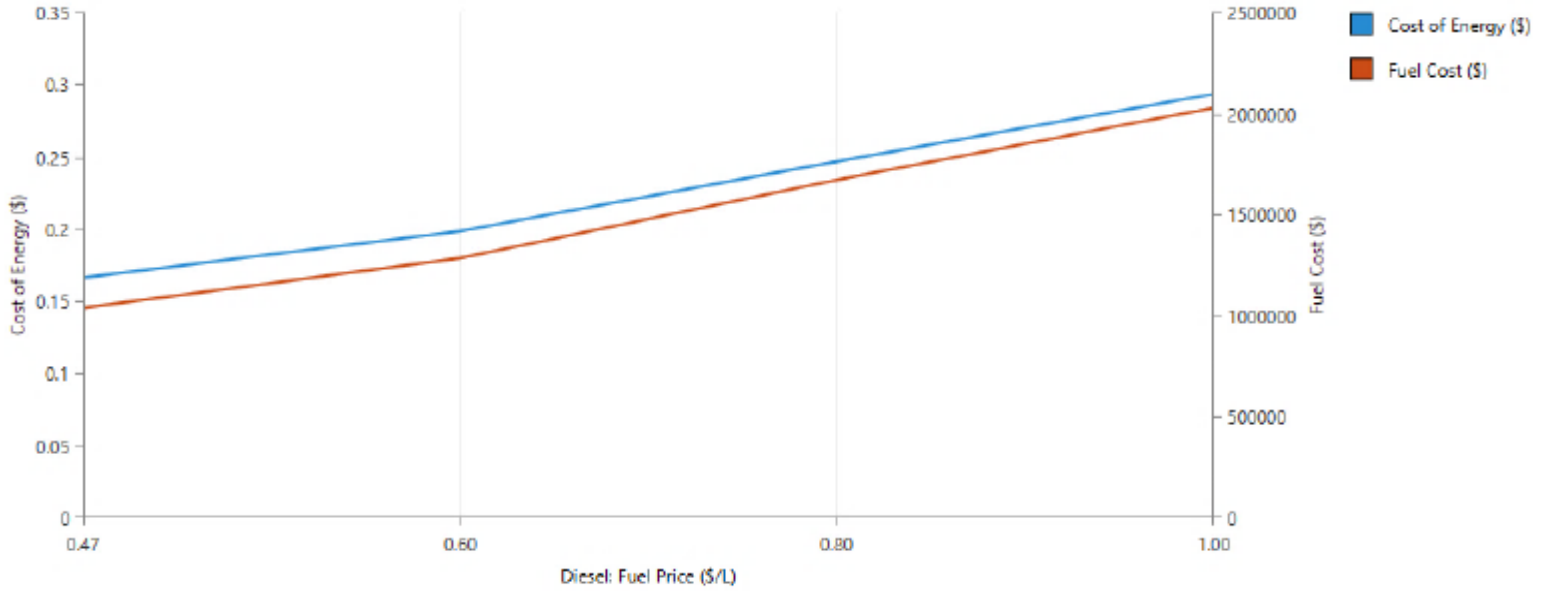
Monthly electric production

PV/Diesel Generator	Simulation Results			
	Hours of Operation (h/year)	*Electrical Production (kWh/year)*	*Fuel Consumption (l/year)*	*Specific Fuel Consumption (l/year)*
DG1	7,496	3,247,995	1,038,497	0.320
DG2	6,578	4,401,830	1,170,047	0.266
PV System	4,379	1,144,215	0,00	0,00

PV/Diesel Generators	Economic characteristics					
	Capital Cost (USD)	*Replacement cost (USD)*	*O&M (USD)*	*Fuel Cost (USD)*	*NPC (USD)*	*COE (USD)*
DG1	1,050,000.00	1,541,790.84	484.52	6,309,835.75	8,838,844.84	0.1663
DG2	1,000,000.00	457,475.92	425.19	7,109,125.85	8,525,639.35	0.1663
PV System	1,350,056.25	0,00	117,262.21	0,00	1,466,408.75	0.1663

Sensitivity analysis

The simulation results presented in previous section are done by taking into an account the current price of diesel which is 0.47 USD/l. By using the HOMER software, we have done the sensitivity analysis for the diesel price increase up to 1USD/liter . The effect of varying diesel price can be observed in a setting range of GHI and valid for the proposed solution. For example, when the fuel price is 0.6 USD/L the COE exceed 0.25 USD/kWh. In the extended version of this paper sensitivity analysis are performed for the load consumption and GHI increase.



Effect of varying diesel price on COE

Conclusion

By proposing hybrid microgrid we are adding 900 kW of PV to the existing system. This would reduce the operating costs to $1.19M/yr. The investment has a payback of 11.4 years and an IRR of 7.86%. The annual production is 1,144,215 kWh/yr. Power output from the Caterpillar Inc. generator system, rated at 1,010 kW using diesel as fuel, is 3,247,995 kWh/yr. Power output from the Caterpillar Inc. generator system, rated at 810 kW using diesel as fuel, is 4,401,830 kWh/yr. Since the system dispatch strategy has been changed the working hours of each generator decreased. This leads to fuel consumption and CO2 emission decrease 5,835,566 kg/year, which is 10% of the existing system. NPC decreased up to 3% due to O&M cost decrease. The capacity shortage is also decreased up to 0.00840%.

The world experience of completed projects shows that autonomous electrification systems based on renewable energy sources are the most acceptable in comparison with systems with traditional sources. However, it should be noted that MG isolated systems require several technical and organizational problems to be solved. In fact, from each implemented project of the MG RES system, some recommendations can be drawn when designing similar projects in similar geographic locations. High penetration of PV system requires the number of calculations and simulation to choose the optimal size of the components, add conversion system or flywheel.

One of the important goals of the conducted research is the efficient use of the potential of renewable resources to cover the needs of industrial enterprises. It has been achieved reliable system with twice less capacity shortage percentage, decreased CO2 emission up to 10% and economically feasible with less O&M cost in comparison with the existing power supply system. Increasing the accuracy of determining the synchronous temporal variability of power generation by solar PV modules and will allow creating a model of a priority combination of PV and generation power values in the current periods of load power changes.

THANK YOU FOR YOUR ATTENTION