Performance Analysis of Garissa Off-Grid Power Station

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Abstract

Off grid power generation options offer a cheaper and sustainable approach to electrify remote and rural communities. The main challenge associated with the use of a single technology is the danger of oversizing of the power systems at the project beginning hence high capital investment. Other limitations are high greenhouse gas emissions and low system reliability. Using a hybrid system and storage can overcome the intermittent nature of renewable energy sources and the problem of oversizing and improve the reliability of energy supply while at the same limiting the environmental impact related to use of fossil fuels. In this study, a performance analysis of Garissa power Station in Kenya was done. The study showed the power station had 6 diesel engine generators with a total installed capacity of 4,257 kW and effective capacity of 1,950 kW against peak demand of between 3600 for Garissa Town at the time of the study. Therefore, the town had a power deficit of 1650 kW during peak hours and therefore requires installed capacity of about 2053 kW (with engines availability factor of 80%) to meet the demand. However, based on the effective capacity factor, up to 3,587kW in new capacity was needed. This deficit was partially addressed temporarily by overhauling two engines of capacity 1064 kW that were out of service and which had been derated from a capacity 674 kW to 250 kW due to mechanical defects. Th study showed that generation improved by 44 by overhaul of engines 1 and 2 even though the generation from engines 5& 6 diminished due to expiry of after sales service and hence delays in maintenance. The study demonstrated the importance of proper and timely maintenance of diesel engines for reliable power supply and challenges associated with use of single technology in power supply for off grid systems.

Keywords: emergency power; off grid power; remote power generation; power generation; Garissa power plant

1. Introduction

The Sustainable Development Goal (SDG) 7 seeks to achieve universal access to modern, affordable, reliable, and sustainable energy by 2030. About 789 million people worldwide had no access to electricity in the year 2020. As a result of this, it is difficult to sustainable development in these mostly rural and remote areas with no access to electricity. A more reliable power supply is necessary to significantly improve the living conditions of remote communities having no access to grid electricity. The benefits of rural electrification include better health care, better education, higher incomes, and employment opportunities, and thus poverty reduction. Off-grid energy solution which include solar, wind systems and diesel generator sets present solutions to electrify the remote off grid regions and help in closing the electricity access gap and lower costs and reduce the waiting times until when compared to access through electricity grid extensions(Aberilla et al., 2020).

Mini grids or microgrids broadly incorporate power generation sources complemented by energy storage systems as a form of a distributed generation to deliver electricity to isolated loads. Mini-grids or microgrids have ability to independently operate with a single or multiple generation sources (hybrid systems), to provide power to underserved populations in rural and remote areas(Hoeck et al., 2022). Access to modern energy, especially electricity, is linked to improvements in health, education, and social welfare.

The problem of low electricity access is more acute with remote communities and communities on islands. One of the characteristics of rural communities is low population density. The families that make up these populations are widely scattered, making it difficult to meet energy demands and making electrical transmission networks expensive. Complex geographic conditions and low energy demand make providing electrical energy by conventional methods impractical (that is, extension of electrical transmission networks and substations), especially in developing countries, where electricity is vital for economic participation and the social welfare of rural communities. Areas that do not have electricity generally also lack essential infrastructure like schools, medical centers, means of communication, access to potable water and others, which is reflects the fact that the human development indices of electrified communities are higher than those of communities without electricity(López-Castrillón et al., 2021).

A widely used method for generating electricity for remote communities is distributed generation systems, which are characterized by using generators to produce electricity by burning fossil fuels, in particular diesel. Diesel generators are relatively inexpensive, the technology is widespread, and the construction time for an electrical station is comparatively short. Remote communities are often not easily accessible, so system maintenance may be a challenge due access challenges to deliver fuel and maintenance parts must be obtained from urban centers, together with continuous fluctuations in fuel prices, this approach is not advisable for poor rural communities. The use of diesel plants in remote transport systems to deliver the fuel, utilities, and technical support. The remoteness of communities also negatively affects the required and frequent maintenance. Diesel remains the main resource for power isolated communities even with the challenges stated. Other negative effects of diesel include emission of greenhouse gases reduced air quality, high storage and transport costs, diesel fuel price instability, high maintenance needs and costs, poor human health, high training needs for operation and maintenance staff. And limited primary energy resource (López-Castrillón et al., 2021).

Use of off-grid hybrid renewable energy systems (HRES-OFF) help mitigate the negative aspects of using diesel to generate electricity. HRES-OFF systems use different renewable and sustainable energy sources to generate electricity. These systems involve different renewable resources to generate electricity, like solar, wind, hydro, geothermal, biomass, biofuel, wave, tidal, and fuel cell energy, among others, as well as energy storage systems like batteries, pumped hydro storage (PHS), hydrogen, flywheel, and others. They can also involve small electrical generators. Solar and wind power are the most often used renewable energy sources worldwide in HRES-OFF. The main studied and implemented HRES-OFF configurations are photovoltaic (PV)–wind–diesel–battery, PV–wind–battery and PV–diesel–battery(López-Castrillón et al., 2021).

Batteries are the main storage method used in HRES-OFF systems, followed by hydrogen, and pumped hydro storage systems, which have limited application owing to the topography in many isolated areas. However, the level of solar radiation decreases at latitudes nearer to the poles, while offshore wind power is greater in middle and high latitudes. Related to stronger and more consistent winds is the generation of waves along coasts, which can be used as an energy source by remote coastal communities. Likewise, tidal changes are a common phenomenon to all the marine coasts of the world and reach extraordinary levels in certain places in the middle and high latitudes, making the tides an alternative source of renewable energy(López-Castrillón et al., 2021).

Investing in a single technology generally results in oversizing systems, which increases initial costs. A hybrid system can overcome the intermittent nature of renewable energy sources and the problem of oversizing and improve the reliability of energy supply. However, hybrid systems have received limited attention because of their greater complexity and the scarcity of works that have considered the question of reliable supply of electricity to rural areas. We expect this study will contribute to decision-making regarding the use and configuration of HRES-OFF systems in remote communities as the use of renewable energy becomes more economically viable due to the increased cost of fossil fuels and lower costs of equipment to make use of renewable energy(López-Castrillón et al., 2021).
(López-Castrillón et al., 2021).

Electrification remains a challenge particularly for countries in sub-Saharan Africa (SSA). Countries with a large portion of the population widely find it very difficult and expensive to connect the people to the national grids. The existence of renewable energy sources even in these rural and remote areas provides an opportunity for decentralized generation. Commonly available energy sources for off grid generation include solar energy, wind, Mini hydro, biomass, but may vary from one place to another. Therefore, off grid generation in remote and rural areas offer a significant opportunity for exploitation of local renewable energy sources and thus play an important role in the global energy transition. (Hoeck et al., 2022).

The main objective of this study is to evaluate the performance an off-grid power station running on diesel engines to supply power to Garissa town in Northeastern Kenya, both before and after overhaul of diesel engines. Measures needed to improve overall performance and reliability of the power station are proposed.

1.1. Problem Statement

The UN recognizes that providing clean and affordable is interconnected peace, poverty reduction and environmental protection as stated in Goal number 7 of the Sustainable Development Goals. It is unfortunate however that close to one billion people globally, of which about 87% live in rural areas, do not have access to electricity. Most of these people rely on traditional sources of energy like biomass, fossil fuels like kerosene, and diesel (Aberilla et al., 2020). It is therefore important to electrify the rural population through off grid technologies and electrification by grid extension.

1.2. Rationale of the Study

There are several challenges and opportunities related to the supply of electricity in rural and remote settlements globally. Powering homes, small businesses and industries using standalone systems makes economic sense whenever access to the grid is impossible and diesel engines are widely used by many in developing countries(Kabeyi, 2012;

Moses Jeremiah B Kabeyi & Akanni O Oludolapo, 2020; Moses Jeremiah Barasa Kabeyi & Akanni O Oludolapo, 2020b). In some cases, stand-alone systems have proved to be more cost-effective compared to extending a the grid whose costs can be in the range from $15,000 to $50,000 per mile(US Department of Energy, 2021). Off grid generation is also an option for people who live on the grid but have the desire to be independent from the power providers or are committed to non-polluting energy resources. Stand-alone systems take the advantage of a combination of techniques and technologies for generation of reliable power, cost reduction, create convenience or minimize inconvenience and exploit locally available natural energy resources(M. Kabeyi & O. Olanrewaju, 2021a; M. J. B. Kabeyi & O. A. Olanrewaju, 2021a, 2021b). Energy options for off grid power supply include fossil fuel, renewable sources like solar, biogas and wind, hybrid systems and demand management to limit electricity requirements (M. J. B. Kabeyi & A. O. Olanrewaju, 2021; M. J. B. Kabeyi & O. A. Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & A O Oludolapo, 2021; US Department of Energy, 2021).

The development of communities is closely related to uninterrupted access to electrical energy. The isolation of communities in remote rural areas hinders the provision of electrical energy by traditional electrical power generation and transmission methods. In 2018, it was reported by the World Bank that about 724 million people had no regular and reliable supply of electrical energy, of which 84.2% live in rural areas isolated from power grids, and the remaining 15.8% are based in urban areas . Electricity is a pillar of economic and social development, as a result of which the rural communities have highest poverty indices and the lowest levels of technological development(López-Castrillón et al., 2021).

2. Generation Planning and Management

The Government of Kenya through the Ministry responsible for Energy has over the years been undertaking power development planning for the country through a sector team constituted from diverse key stakeholders. Updates of the Least Cost Power Development Plan (LCPDP) are prepared biennially covering 20-year periods, and five-year medium-term plans compiled in alternate years. This report presents a 10 year Least Cost Power Generation Expansion Plan (LCPDP) covering the period 2021-2030 and is derived from a longer term LCPDP prepared for the period 2020-2040. The report was prepared as part of national government undertakings for post COVID-19 development support program and the attendant engagements with development partners. The update was deemed necessary to make the long-term planning assumptions more predictable given the relative certainty in planning for a 10 years' period compared to 20 years. Power planning is guided by the existing national policy frameworks as well as existing legislation intended to govern stakeholders on power supply over time(Ministry of Energy, 2021).

The Energy and Petroleum Regulatory Authority (EPRA) formerly ERC has been mandated to coordinate preparation of sector plans. EPRA established an electricity sub-sector Technical Committee of the LCPDP comprising all sector agencies. The Energy Act No 1 of 2019 vested this mandate on the Ministry of Energy going forward as articulated in part II section 5 of the act. This report is hence prepared within the framework of the Energy Act 2019 but tailored to addressing specific challenges the sector is facing post COVID 19. Planning for power supply in the country involves integrating sequenced planned generation with the demand forecast. The objective is to ensure that the demand-supply balance is not skewed too heavily towards supply to leave the sector with stranded generation investments and the attendant high system costs. In addition, the plan focuses on system requirements for integration of renewable energy technologies namely solar and wind and provides guidance on possible extra investment costs targeted at stabilizing power in Kenya at affordable tariffs(Ministry of Energy, 2021).

3. Off grid Plant Equipment

Common facilities for off grid power supply include photovoltaic panels, a wind turbine, small hydropower system, diesel engines and other prime movers like petrol engines, gas turbines, and fuel cells etc. There is also need for additional equipment called "balance-of-system" used for conditioning and enabling safe transmission of power to consumers. The equipment includes Storage batteries, charge controller, Safety equipment, power conditioning equipment and power meters and instrumentation devices and systems (US Department of Energy, 2021).

Electricity solutions to rural areas may be classified as large-scale grid extension or localized small-scale distributed generation. An immediate answer to many governments, especially the developing countries, is to improve rural electrification rates is grid extension. However, grid extension may prove unviable on technical and economic grounds which necessitates deployment of off-grid installations. Diesel generators have historically offered off grid solutions in many countries. However due to greater environmental awareness, there is growing interest in energy sources of energy for rural electrification(Aberilla et al., 2020). Optional technologies for both home- and community-scale power systems include solar photovoltaics (PV), diesel generators, wind turbines, and batteries (Aberilla et al., 2020).

According to the International Energy Agency (IEA), about 60% of new capacity which is an equivalent of 571 TWh by the year 2030 for rural areas will be derived from renewable sources of energy. It is further expected that about 70% of rural connections will be off grid by the year 2030. Studies by the World Bank identify renewable energy technologies like wind and biomass as more economical than diesel or gasoline generators for off-grid power generation particularly in small scale applications(Aberilla et al., 2020) Therefore the renewable energy (RE) is a significant part of rural electrification plans, way forward.

4. Power Plant Status

4.1. Installed Capacity

Garissa power plant has got 6 diesel engines of varying designs and capacities as showman in table 1 below.

Table 1: Installed capacity of Garissa Off grid power plant

Engine N0.	Model	Year of Installation	Installed Capacity (kW)	Effective Capacity (kW)	Capacity factor	Status
1	Man Diesel	1994	1064	0	0	On Forced Outage
2	Wartsila	1994	674	250	0.37	Operating
3	Wartsila	1994	674	0	0	Retired (non-operational
4	Caterpillar	2005	1045	1000	0.96	Operating
5	Perkins	2009	400	350	0.86	Operating
6	Perkins	2009	400	350	0.86	Operating
TOTAL (MARCH 2010)			4257	1,950	0.46	

From table 1, it is noted that Garissa power station has installed capacity of 4.257 MW. However, the effective capacity is 1.95 MW hence a capacity factor of 0.458. The Man engine of installed capacity 1064 kWe was on forced outage during the study while engine 3 (Warstilla) was retired after a major breakdown that was declared technically uneconomical to repair.

It is observed that caterpillar engine (Engine 4) had the highest capacity factor of 0.96 mainly because it had just come out of a major overhaul and had a high level of reliability. Engine 1 (Man diesel engine) was on forced outage for over 3 years occasioned by a delay in procurement of spare parts. The two Perkins engines were still under warranty and hence maintained by the supplier and hence timely well maintained leading to high reliability and capacity factor of 0.86. The operating Wartsila engine (Engine 2) was derated due to technical limitations and was operating at a capacity factor of 0.37 which is below average performance. The engine was overheating often and poorly maintained due to lack of spares and support from the manufacturer.

4.2. Power Deficit

Garissa town is the regional capital of Northeastern Kenya that has been witnessing high growth rates in terms of human population settlements and economic activities exerting pressure on the of grid station to supply power. On the hand, the power station has a challenge of maintaining old and obsolete power infrastructure amid challenges of spare parts procurement due to government-imposed procurement regulations and procedures that hamper efficiency. Table 2 is a summary of the power station capacity, demand and overall performance in generation and supply of power.

Table 2: Power plant capacities

	Particulars	Capacities
1	Installed capacity	4,257 kW
2	Effective capacity	1,950 kW
3	Peak demand	3,600 kW
4	Deficit	1,650 kW
5	Average Capacity factor	0.46
6	Required extra capacity	1650/0.46=3,587kW

From table 2, it is noted that the electricity peak demand at the time of investigation was 3.6 MW, against an installed capacity of 4,257 kW, but just 1,950 kW as the effective capacity. This implies that the deficit based on peak demand and effective capacity 1,650 kW. The average capacity factor for the power station is 0.46, which implies that the power station is utilizing just 46% of its installed power station capacity. If this capacity factor is retained, then a massive 3,587 kW extra generation capacity is needed to supply reliable power to the off-grid consumers.

5. Improvement Options

The analysis of the power plant capacity shows that it has installed capacity 4,257 kW, but the effective capacity is 1,957 kW against a peak demand of 3,600 kW growing at an average annual rate of 10- 20% of the current demand. Therefore, besides improving the performance of existing generators, it is necessary to plan for ever growing demand.

The optimum capacity factor for a diesel engine is 70 to 90%, hence applying an average of 80% as the capacity factor, the power station optimum capacity to meet current demand based on peak demand of 3.600 kW is 5,600 kW of power plant capacity(Moses Kabeyi & Oludolapo Olanrewaju, 2022; Moses Kabeyi & Oludolapo Olanrewaju, 2022). Based on the prevailing circumstances, the improvement needed to meet the current and future demand can be done in two phases or two options i.e.

i.) Overhaul the exiting engines to increase generation and improve system reliability.
ii.) Expand the capacity of the power station to meet both current and future demand of the power station.

The immediate option to improve performance is to overhaul the engines starting with Engine 1 (Man engine) to inject 1 MW power to the Mini grid.

5.1. Performance Before Overhaul of Engine 1 and Engine 2

In this case, KenGen procured spare parts and a major maintenance was carried out on Engine 1 which was on forced outage. This improved the output of the station as demonstrated by comparing the performance of the powerplant before and after the overhaul. Table 3 shows the performance of the power station when engine 1 was not available due to mechanical breakdown of various parts and systems that needed overhaul or major maintenance.

Table 3: Generation data for before maintenance of Engine 4

Date	Eng. 1	Eng.2	Eng.3	Eng.4	Eng5&6	Gen.	Aux.
1/6/2009	0	3430	0	17700	7550	28680	1100
2/6/2009	0	4780	0	18000	7050	29830	1190
3/6/2009	0	4470	0	21400	7200	33070	1150
4/6/2009	0	4920	0	1900	5750	12570	1140
5/6/2009	0	4480	0	19200	5850	29530	1130
6/6/2009	0	3190	0	19300	8000	30490	1020

7/6/2009	0	3320	0	17000	8150	28470	1080
8/6/2009	0	3710	0	19600	9850	33160	1080
9/6/2009	0	3820	0	19400	10250	33470	1070
10/6/2009	0	4070	0	20900	10800	35770	1150
11/6/2009	0	5130	0	20500	9250	34880	1210
12/6/2009	0	4190	0	20200	11100	35490	1150
13/06/2009	0	4930	0	20300	8130	33360	1220
14/06/2009	0	3820	0	18400	10050	32270	1120
15/06/2009	0	3890	0	19100	10100	33090	1100
16/06/2009	0	3710	0	20000	10450	34160	1100
17/06/2009	0	4740	0	19700	8650	33090	1190
18/06/2009	0	3780	0	20000	10560	34340	1110
19/06/2009	0	3760	0	14800	9700	28260	1000
20/06/2009	0	2290	0	20100	10450	32840	940
21/06/2009	0	3850	0	19000	10400	33250	1060
22/06/2009	0	4710	0	19200	8550	32460	1100
23/06/2009	0	3740	0	17400	9550	30690	1030
24/06/2009	0	3660	0	19300	9250	32210	1050
25/06/2009	0	3780	0	20800	9250	33830	1020
26/06/2009	0	3870	0	18100	9100	31070	1020
27/06/2009	0	3890	0	18600	7700	30190	1110
28/06/2009	0	3240	0	20300	9600	33140	1050
29/06/2009	0	4740	0	20000	8250	32990	1130
30/06/2009	0		0			0	
TOTAL	0	115910	0	540200	260540	916650	31820

Table 3 shows the power plant generation performance with Engine 4 down on forced outage. It is noted that generation for the month investigated. Showed no generation for engine 4, 115910 kWhr for engine 2, no generation for engine 3 which was declared obsolete, 540,200 kWhr for Engine 4, and 260,540 from Engine 5 &6 which are two different engines, but they share an energy meter. The total generation for the month was 916,650 but auxiliary consumption was 31,820 kWhr.

5.2. Generation After Engine 4 Overhaul

The power system was characterized by constant power rationing, frequent trips on overload and negative publicity due to poor performance with many public protests by consumers facing the consequences of unreliable power supply. Unfortunately, by the time Engine 1 was being overhauled with major maintenance, Engine 2 was also being derated due to overheating and the challenges and needed maintenance too. This demonstrates the challenges of using diesel power plants for base load and peak power supply. Table 4 shows the performance of the power plant after maintenance of both Engine 1 and engine 2.

Table 4: Power generation data for August 2011 after engines 1 and 2 overhaul.

Date	Eng.1	Eng. 2	Eng. 3	Eng. 4	- Eng.5&6
1-Aug	15650	4370	0	18700	2330
2-Aug	15600	1700	0	19800	5010
3-Aug	16000	1190	0	20300	4870
4-Aug	17050	1350	0	18800	4790
5-Aug	16950	4360	0	19700	2330
6-Aug	16400	5460	0	16300	2310
7-Aug	15150	5480	0	17800	2120
8-Aug	16200	4820	0	17100	2210
9-Aug	16550	5370	0	17800	1670
10-Aug	16150	5290	0	19200	2430
11-Aug	16700	2330	0	19300	5930
12-Aug	15550	1330	0	19300	7710
13-Aug	16050	3870	0	18900	4460
14-Aug	15800	2980	0	19100	5060
15-Aug	12500	5490	0	20600	4330
16-Aug	16000	750	0	20200	5640
17-Aug	16550	0	0	19100	7230
18-Aug	16250	1710	0	19800	7030
19-Aug	17150	3940	0	20900	2820
20-Aug	15600	1930	0	17900	4950
21-Aug	15400	5860	0	19100	1930
22-Aug	15000	3640	0	20400	3140
23-Aug	16300	4455	0	22200	3010
24-Aug	9050	4505	0	19600	9010
25-Aug	17000	2130	0	20300	6810
26-Aug	12350	770	0	21800	6020
27-Aug	5550	6920	0	21600	9760
28-Aug	15900	0	0	19000	7450
29-Aug	16450	2000	0	15400	7170
30-Aug	14700	2280	0	13400	8810
31-Aug	17450	0	0	20600	8480
TOTAL	475000	96280	0	594000	156820

From table 4, it is noted that the generation output of the power station significantly improved when both engines 1 and 2 were simultaneously subjected to major maintenance. It is observed that monthly output for engine 1 was 475000, Engine 2 was 96280, Engine 3 remained non-operational, Engine output was 594,000 while average monthly output for engine 5 and 6 which share an energy meter was 156,820 kWhrs.

6. Results and Discussion

The use of standalone systems or off grid systems to supply electricity to homes or small businesses by applying small renewable energy systems makes economic sense and appeals to their environmental concerns. Investing in. Off grid systems can be more cost-effective compared with extending the grid to remote or far away locations from the electricity grid. Off grid systems are also occasionally used by consumers who are close to the grid but wish to obtain energy independence from the utility or demonstrate a commitment to non-polluting energy sources.

Successful off grid systems generally take advantage techniques and technologies to generate reliable electricity, minimise inconvenience, reduce costs, and reduce environmental impacts. Sustainable strategies may also involve use of fossil fuel or renewable hybrid systems and demand management. The main challenge is balancing costs which cost incurred in some additional equipment to condition and safely transmit power to the load that will use it. Various equipment of the balancing system include:

i.) Storage batteries
ii.) Charge controller
iii.) Equipment for conditioning power
iv.) Power system safety equipment

This study showed that Garissa power station has a challenge of low capacity and hence the demand it was always less than available generation. Among the reasons for the deficit is use of old and obsolete engines, failure to adhere to maintenance schedules due to lack of spare parts, high and ever-growing demand, limited diversity as the station relies entirely on diesel generators for baseload and peak load applications.

Table 5: Engine generation before and after overhaul f Engine 1

	Engine	Generation before overhaul (kWh)	Generation after overhaul (kWh)	Differences (kWh)	Percentage (%)
1	Engine 1	0	475000	-	-
2	Engine 2	115,910	96,280	-19,630	-16.94%
3	Engine 3	0	0	0	0
4	Engine 4	540,200	594,000	53,800	9.95%
5	Engine 5 and 6	260,540	156820	-103, 720	-39.81%
6	Total generation (monthly)	916650	1,322,100	405,450	44.23%

From table 5, it is noted that based on performance before and after the major overhaul for engines 1, the total generation improved by an average of 44.23%, engine 3 remained out of operation hence no generation, engines 5 and 6 declined by 39.81 in generation due to more forced outages and derating, engine 2 also reduced its total generation by 16.94 due to outages. Engine 1, which was out of operation on forced outage generated an average of 475,000 kWhrs.

An immediate answer to many governments, especially the developing countries, is to improve rural electrification rates by grid extension. However, grid extension may prove unviable on technical and economic grounds which necessitates deployment of off-grid installations. Diesel generators have historically offered off grid solutions in many countries, even though they have very many challenges like unsuitability for base load applications due to high costs and emissions.

Unlike fossil fuels, most renewable resources are more equitably distributed and used widely in different locations. Energy production by renewable resources like hydro, solar, wind, geothermal, biomass and marine energy increased globally from 93,776 TWh in 1965 to 667,349 TWh in 2018, which is an increase of about 712%. According to the International Energy Agency (IEA) renewables like hydroelectricity accounted for 25.3% of the global electrical generation of 2017. Availability of renewable energy sources for off grid generation varies from one place to another e.g., areas around water sources have huge availability of water hydro energy resources but limited access to biomass and geothermal energy. They also have but significant access to strong offshore winds and solar. On the other hand remote islands have more access to water and biomass for small-scale hydro power, high and low enthalpy geothermal energy source, and widespread access to wind and solar radiation (López-Castrillón et al., 2021).

Diesel is the main fuel for use in industrial, transport, and in diesel power plants; unfortunately it is polluting and non-renewable (Arefin et al., 2020). Hence, there is a dual need to reduce emissions and cost of power from diesel engine power plants (Niemi, 1997). Reliance on diesel power, especially during low rains contributes to the high cost of grid electricity. The current trend of using diesel fuel has a negative impact to consumers in terms of huge electricity bills (Andae, 2017).The environmental impact of diesel power plants includes emission of So_x and NO_X emissions e.g. SO_2 which undergoes chemical reactions with moisture in the atmosphere to form sulfuric acid (Barasa, 2020; Jeremiah, 2018). The emissions also react with the ozone layer leading to its depletion(M J B Kabeyi & A O Oludolapo, 2021). The greenhouse gases are responsible for the global warming in addition to other health effects to humans like chronic respiratory diseases, lung cancer, heart diseases, and damage to brain, liver and kidneys(M. J. B. Kabeyi & A. O. Olanrewaju, 2020; M J B Kabeyi & A O Oludolapo, 2020a, 2020b).

It costs about KES 6.00 to produce 1 kWh of electricity using natural gas (Eurostat, 2020) which is much lower compared to diesel power generation which costs about KES 30.00 (Andae, 2017; Kabeyi & O. A. Olanrewaju, 2020). Therefore, conversion to natural gas will reduce the cost of power generation. Diesel generators (DG) are economically cheaper to purchase, but technically more y expensive to operate and maintain, especially during partial load conditions which are less efficient because of high fuel cost delivered to the power plant from far away. Diesel engines also have many moving parts leading to high rates of failure and increased cost of operation and maintenance(M. Kabeyi & O. Olanrewaju, 2021a; M. J. B. Kabeyi & O. A. Olanrewaju, 2021b). As a double coincidence, diesel fuel is often delivered to remote power stations by tracks and rail powered by diesel engines. On the contrary large-scale gas supply is often delivered by gas pipelines which are cheaper to operate and maintain(M. Kabeyi & O. Olanrewaju, 2021b; Moses Jeremiah Barasa Kabeyi & Akanni O Oludolapo, 2020a).

· As far as the environment is concerned, the diesel power plants have significant environmental impacts besides the power plants being non-optimal and expensive to operate and maintain. Operation of diesel engines contaminates local air and soil and emits significant amounts of greenhouse gases. Since the use of these diesel generators is not optimal and is additionally very expensive, there is growing need to identify alternative fuels and means of generation to reduce cost of generation and environmental impact of diesel power plants (Issa et al., 2019).

7. Conclusion

The power station under the study had 6 diesel engine generators with a total installed capacity of 4,257 kW and effective capacity of 1,950 kW against peak demand of between 3600 for Garissa Town at the time of the study. Therefore, the town had a power deficit of 1650 kW during peak hours and therefore requires installed capacity of about 2053 kW (with engines availability factor of 80%) to meet the demand. However, based on the effective capacity factor, up to 3,587kW in new capacity was needed. This demand could be met by repairing Engine 1 with capacity of 1064 kW which was on forced outage, Engine 2 of capacity 674 kW which had been derated to 250 kW, and the engines 5 and 6 also performing below optimum capacity. This could solve the problem in the short term. However, as a long-term measure extra capacity from the new generation is needed to take care of emergencies and the ever-growing demand.

The main challenge facing Garissa power station is the use of a single technology which generally leads to oversizing of the power systems at the start of the project hence high capital investment. Other limitations are high greenhouse gas emissions and low system reliability. Using a hybrid system and storage can overcome the intermittent nature of renewable energy sources and the problem of oversizing and improve the reliability of energy supply while at the same limiting the environmental impact related to use of fossil fuels.

This study demonstrated the serious challenges resulting from use of diesel generators as single energy sources for the off grid power and the significance of proper and timely maintenance of engine prime movers for power plants to guarantee reliability and capacity in power generation.

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