Potential, Prospects and Challenges Associated with the Implementation of Photovoltaic Solar Energy in Zimbabwe

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Abstract

Renewable energy is one of the critical solutions to address the ever-increasing demand for energy. In developing countries such as Zimbabwe where the conventional generation hardly sustains half of the nation's energy demands, renewable energy solutions are compensating for the deficit. Among these renewables, solar energy technologies have witnessed rapid growth. In most cases, solar energy installers assume to have all the knowledge required in the field. However, many technical barriers still exist within the field of solar energy systems. For solar energy systems which are synchronized to the grid, the integration of these renewables pose a serious stability and protection threat to the already unstable and even stable grids. In this paper, some of the technical problems being faced are discussed. Policy issues as well as the possible solutions needed in order to realize full, unhindered growth of solar energy are addressed.

Keywords
Grid Integration, Renewable Energy, Stability, Solar Energy.

1. Introduction

Renewable energy sources include but not limited to solar energy, wind energy and biomass. In developing countries such as Zimbabwe solar energy or photovoltaic (PV) systems are leading on renewables. PV systems are vital in achieving sustainable development goals. Goal number seven aims at achieving affordable and clean energy. Conventional Power Stations which are coal or oil-fired produce toxic gases into the atmosphere, which can be totally eliminated through the use of PV systems. The setting out of sustainable power PV sources is a significant switch to decarbonize the power sector and moderate the impacts of atmosphere (Lewis 2007).
The adoption of renewables is also a significant move in reducing the margin between generation and demand. In the most recent decades, there has been phenomenal development in two advances in particular solar photovoltaics (PV) and wind power. In Zimbabwe, solar PV systems have witnessed a more significant growth as compared to wind power. Worldly trends show that the yearly increments of 27% and 13% have been witnessed in the past decade for PV and wind systems, respectively, Kabir et al. (2018). These PV systems have played a significant role in reducing the generation and demand energy gap. In Zimbabwe alone, conventional power plants hardy produce 1500MW when the demand is estimated to be beyond 2500MW.
Just as the growth of variable renewables continues to increase and the benefits being reaped from these sources, so are the PV systems. However, this growth lead to various challenges in power frameworks ranging from the power system network itself to social, economic and even political challenges (Lewis and Nocera 2006). Inability to manage these difficulties may endanger power systems unwavering quality or on the other hand, the accomplishment of affordable and clean energy targets. Different arrangement advances are accessible to alleviate these difficulties. The surviving writing, in any case, needs lucidity on

the extent of the challenges and the arrangement innovations to address them. The interrelation network of difficulties also, solution technologies must be created in order to deal with the challenges at a national level. The arrangement capability of various advancements can thus help organize arrangement innovations notwithstanding zeroing in on savvy choices. It is also necessary to distinguish gatherings of arrangement innovations that can help relieve particular challenges.

Generally, the significant challenges with renewable include their intermittent nature and large space requirements. These issues if left alone or are improperly addressed leads to severe challenges in existing power frameworks. When interconnected to the electric grid network, the variability of PV systems can severely impact on the network stability (Hossain and Mahmud 2014). Contextually, challenges are defined as causes that negatively influence the performance of an interconnected power system. These challenges can be tended to by different technological advances.

In our context, these new or changed advances moderate the impacts of these challenges. Solution-based technologies are significant for coordinating renewables into power frameworks and at last accomplishing decarbonization targets, however sending these advancements may be difficult, Sinsel et al. (2020). This is due to the fact that the decision of solution technology advances relies upon different components, such as cost, development, scope of utilizations, and inclinations of firms or policymakers. The choice on the utilization of a specific technology is usually not made by a single entity, instead by various stakeholders, including system operators, utilities or regulators. Also, the need for solution technology varies regionally according to the renewable share in power generator portfolios or individual power system configurations such as the island of rigidly connected systems Xu et al. (2019).

Energy transition researchers and specialists lack adequate clarity concerning the extent of challenges and the accessible technologies to address these challenges. In some areas, experts analyze the challenges and propose explicit solution technology advances, for example, voltage management solutions for transmission and distribution grids with high renewable penetration. However, these proposals may underestimate solution technologies that can address a more extensive scope of difficulties, for example, battery storage, which can likewise help to address generation adequacy challenges. In outline, while singular challenges and solution technologies might be known, the literature comes up short on a clear overview of each (Hache and Palle 2019). This is explicitly significant for energy transition researchers as well as other stakeholders. This study offers such an overview by tending to the question of what are the challenges of renewable integration also, and what can be done to address some of these challenges.

This study is organized as follows: Section 2 gives an overview of solar energy systems in Zimbabwe, its potential and some completed projects. In Section 3, the current global status for solar energy is presented. The recent statistics and countries leading on the solar PV projects are given. Issues to do with regulation and policy frameworks are then described in section 4. Section 5 deals with challenges and advantages associated with solar technologies. The challenges and areas of research which are arising due to the adoption of solar technologies are presented in section six. Section 7 finishes up with the conclusions gathered from this study.

2. Solar Energy Systems in Zimbabwe

This section presents an overview of solar energy systems in Zimbabwe. The area is organized in two sections. To start with, solar energy potential in Zimbabwe is discussed. The subsequent section introduces various projects which have been completed and the potential that the nation has in increasing its solar energy penetration.

2.1 Solar energy potential in Zimbabwe

The physical potential Zimbabwe has in electricity generation from sources such as hydro, solar, and biomass is innumerable Murdock et al. (2019). Solar energy alone if properly harvested, stored and transmitted to various demands points, can power more than 50% of the nation’s primary needs. Currently, only a fraction of the country’s solar energy potential has been exploited and remain hugely underutilized. Solar energy projects must continue to increase as wind, and geothermal energy have less potential in

Zimbabwe. Figure 1 shows the potential of solar energy in Zimbabwe; the data is courtesy of the World Bank Source on Global Solar Atlas 2.0 of Solar resource data gathered using Solargis. The average PV output in Zimbabwe is 5.5 kWh/kWp/day with the north and west regions of the country having the highest power potential.

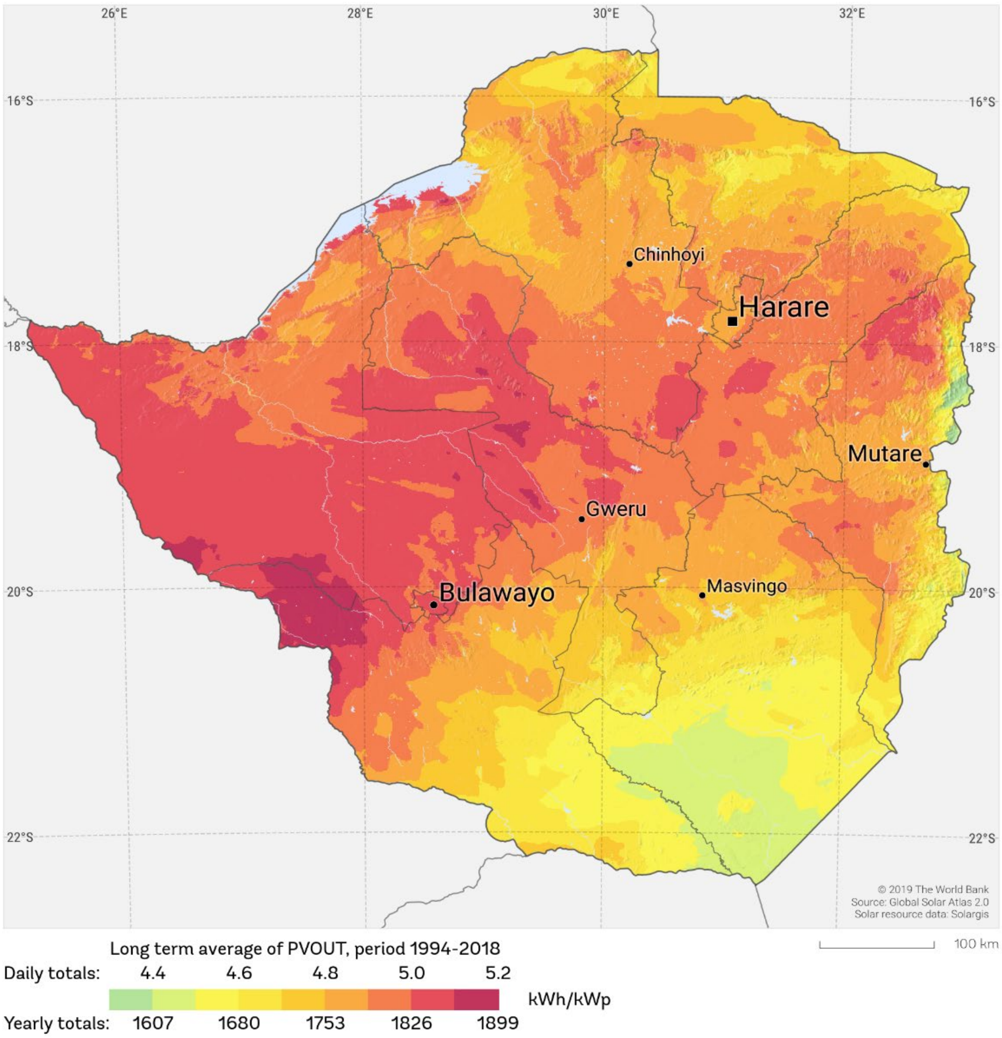

Figure 1: Photovoltaic Power Potential in Zimbabwe

2.2 Solar projects in Zimbabwe

The total amount of power that can be produced in Zimbabwe is well over 1 GW. Currently, the installed solar power capacity in both rural and urban homesteads is still low with minimal capacity hardly exceeding 3kW per household, for companies and other more prominent organizations the capacity can be above 500kW. Nevertheless, the total installed capacity countrywide is still less the 200MW. A number of small and medium-sized companies that focus on the installation of PV and solar water heaters have increased. Some of the projects which have been done by one company in Zimbabwe in the last two years are given in Table. 1. The projects have the option for linking to the grid and are of various capacities

Generally, the project flow has three main stages, which are: Site assessment; here, the proposed site where the project is to be done is to be assessed. Panel mounting position, existing MDBs, mains, protection, earth leakage devices are all determined. Energy audit is also done to determine the current and projected consumption. The second stage is Design and solution. Using the experience of designers and the help of simulation software, the most favorable design is produced. The solution is also optimized and made as practical as possible. Lastly, there is Implementation. This is the final stage before commissioning where the equipment is purchased and brought to site for mounting and installation.

Table 1. Solar Projects in Zimbabwe

Solar Projects in Zimbabwe 2018-2020		
Site Name	***Province***	***size/ kWp***
Econet Graniteside	Harare	101.76
Econet Msasa	Harare	105
Econet Livingstone	Harare	31.2
Nehimba Lodge	Matebeleland	59.15
CTDT	Harare	14.85
Mupambe School	Matebeleland	15.6
EcoSwitch-Willowvale1	Harare	466.7
Kefalos Dairy	Harare	600.6
Schweppes	Harare	954.72
Bomani Lodge	Matebeleland	27.3
Camelthon Lodge	Matebeleland	27.3
Blue Swallow Lodge	Manicaland	62.4
EcoBSC-Mutare	Manicaland	108.9
EcoBSC-Masvingo	Masvingo	85.8
EcoBSC-Gweru	Midlands	85.8
EcoBSC-Bulawayo	Matebeleland	29.25
Surrey Group	Mashonaland east	117
Zimbabwe Agricultural Society1	Harare	221.2
Zimbabwe Agricultural Society2	Harare	166
Pockets Hill-P1A	Harare	100
Pockets Hill-P1B	Harare	100
Pockets Hill-P2A	Harare	800
TOTAL Westgate	Harare	17.7
TOTAL Emerald Hill	Harare	29.4
TOTAL Rusape1	Manicaland	29.4

3. Current global status for solar energy

The main challenge associated with renewables is their intermittent nature. The overall power output is dependent on geographical location and the time of the day. Despite all these challenges, most countries have taken an advanced step in the adoption of renewables. This is mainly due to newer technologies which enables more energy to be harnessed from the renewables. In most countries, the Solar PV capacities had steadily increased to about 510MW in 2019 from 5MW in 2005. Figure.2 shows countries with the leading share in PV energy systems. China is leading with an estimated installed capacity of 204GW. European countries are also dominating in the overall PV systems installed with Germany having increased to 49GW. Germany is targeting a 100% fully renewable grid by 2050 Hansen et al. (2020). Through its partnership with China, Zimbabwe can grow its PV share to meet most of the nation's needs

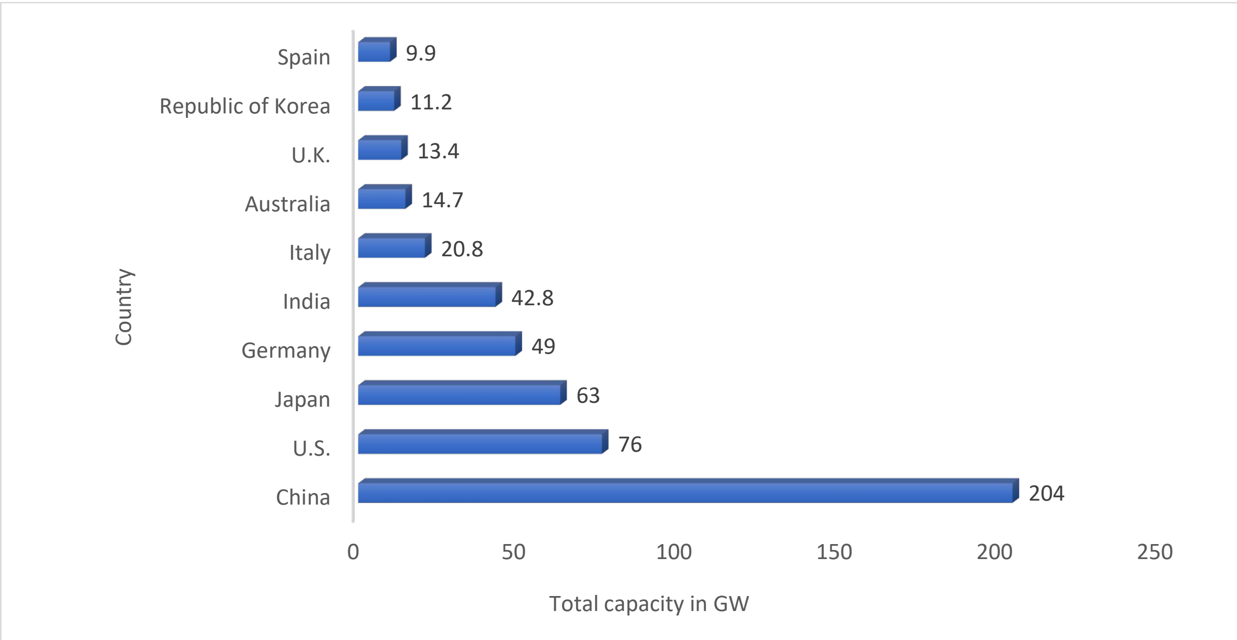

Figure 2. Global Solar photovoltaic capacity as of 2019, by select country

4. Regulation and policy frameworks in Zimbabwe

In line with the 2015 Paris Agreement, some progress is being made in Zimbabwe to promote the adoption of solar PV as a way of mitigating gas emissions. Policies that help to address climate change may not be coupled explicitly with renewables, but they indirectly promote the use of renewables by mandating the reduction of technologies that emit greenhouse gas. To stimulate the solar industry growth, the government of Zimbabwe proposed the removal of customs duty on solar-related products in the 2020 national budget. In recent years a lot of independent power producer licenses have been issued. By the end of 2019, over 42 licenses for solar power projects had been issued by ZERA. The private sector is making huge investments in solar projects as witnessed by the growing number of solar business start-ups.

The energy sector reforms are being spearheaded by the Ministry of Energy and Power development that has a vision of achieving universal access to sustainable energy by 2030 (Mzezewa and Murove 2017). The power utility is also planning to boost the solar PV sector as evidenced by tenders that have already been awarded by the Zimbabwe Power Company and also the invitation in 2020 to bidders by the ZETDC for the contracting of 500 MW of PV. The launch of the National Renewable Energy Policy seeks to attract investments in the renewable energy. Tax holidays of 5% for renewable energy projects for the initial 5 years have been proposed. The following income tax deductions are available: first five years its 0%, the second five years its 15% and after ten years it will be 30%. The Statutory Instrument 86 of 2018 on Electricity (Net Metering) Regulations is a huge step in promoting the production of excess power from solar PV, which will be fed in the national grid. The Rural Electrification Agency is making some strides in implementing solar projects in areas that are far from the grid. Some very remote areas which were underdeveloped as compared to others are also witnessing huge investments for solar power projects, for example, the Kanyemba solar power initiative which will see a 1 MW plant being set up.

The goals and objectives of the Zimbabwe National Renewable Energy Policy (NREP) included the installation of 1100 MW of renewables by 2025 and 2100 MW of renewables by 2030 Ghussain, et al (2019). The NREP also reports that the Zimbabwean government will introduce mechanisms for funding renewable energy systems as well as implementing a renewable energy technologies program that encourages Independent Power Producers (IPPs) to invest in renewable energy projects in Zimbabwe. Additionally, a fund is to be established by the Ministry of Energy to promote solar energy to address the electricity crisis. Currently the solar PV sector is dominated by independent power producers and the tenders issued by the power utilities have not yet started to generate power to be integrated into the grid. Companies such as Nyangani renewable energy and Centragrid have started feeding to the national grid while the Harava solar project is almost complete to be integrated. Renewable Energy developers can benefit from a ten-year income tax holiday offered to investors within the energy, water and sanitation and transport sectors.

5. Challenges and advantages of solar energy

Solar power is a steady power supply that is widely and vastly accessible to all and would offer energy security and energy independence to all. Such a tendency is vastly necessary not just for people but conjointly for the socio-economic success of corporations, societies, and countries. Yet, solar energy is currently being adopted as a natural and substantial a part of electricity generation in several developed and developing countries to satisfy energy demands. Nevertheless, there are several challenges and advantages linked to its use.

5.1 Challenges of solar energy technologies

The solar PV industry is facing some challenges in Zimbabwe, and its growth is not as was projected. One major challenge is the initial cost of solar systems which not affordable to many, especially in the remote areas of the country where most people don't have access to electricity. The initial setup cost is the foremost important challenge of the alternative energy system; as an example, the typical value per watt for solar energy was around $4.00 within the USA in early 2016 Fu et al. (2009). Supporting a mean solar energy system of five kilowatts per house, the system would value $13,000 once the Federal solar tax credit is included (hence decreasing the prices by 30%). However, with advances in technologies in some nations such as China, it's now around $0.20 per watt. Regardless, protracted payback periods and small revenue streams conjointly scale back the benefits for such systems. Moreover, the efficiencies of most domestic solar panels are in the range of 10–20%, which is another disadvantage of solar technology. However, better performing solar panels also are obtainable at higher costs.
Policy and regulatory instability challenges is also inhibiting solar PV from becoming a major electricity source worldwide. The absence of cost-effective storage systems makes it difficult for solar energy to become a primary source of energy. Zimbabwe as a nation is also facing challenges with poor quality solar panels which are flooding the market this can be controlled with proper regulation, with some panels failing within the first 5years against the manufacturer guarantee of over 25years. This has seen most customers being short-changed of their hard-earned income.The performance limitations of different elements like batteries, inverters, etc. are other areas which can be improved. Short battery lifetimes and the safe disposal of spent batteries are another concern in solar energy systems. In addition, batteries are typically large and heavy, hence requiring a considerable amount of space for storing. Besides, as solar panels are made up of rare or precious metals like silver, tellurium, or indium, inadequate facilities exist that can recycle spent panels.
In as much as the proposed moved by the regulatory authority to have solar installers licensed is a positive development, its downside is that it may inhibit growth if not properly handled. Grid instability caused by the injection of solar energy in the national grid is still a major challenge. For any network, proper system studies must be carried out to determine the proper position for grid integration. Generally, areas close the loads are the best but may also introduce some unwanted system losses in some cases. Vandalism and theft of installed solar project components is a problem; some people end up not opting for solar projects if they don't have enough security mechanisms. Factors related to the smooth-running of systems such as skilled personnel to meet the growing demands for installation, maintenance, inspection, repair, and analysis of solar energy systems are another constraint as well. Moreover, a scarcity of necessary technical knowhow on the user's behalf (especially in rural areas of the developing world) with relevance solar energy systems may result in irregular usage, overcharging the battery, polarity reversal, by-passing the charge controller, etc. which might all cause system damages. Also, the credibility of cracks among the PV module, water intrusion, exposure to dirt, and algal growth will significantly lower the performance of the system.

Toxic semiconductor compound, silicon tetrachloride, a by-product of the polysilicon production method, is expensive (about $84,500 per ton) to process and recycle. The semiconductor compound is commonly dumped by most manufacturing companies without correct pre-disposal treatment. Another obvious disadvantage is that solar energy is mainly harvested during the day and works most expeditiously when it is sunny. Consequently, solar energy is probably not the foremost reliable supply of energy in regions with unsustainable weather or climate conditions. Moreover, air pollution levels at the installation area may also affect the effectiveness of the solar cells Radivojević et al. 2015. Exposure to exhaust fumes and aerosols was found to scale back the current of semiconductor solar cells by 10 percent and 7%, severally. Finally, huge plots of land are typically needed to produce solar energy at large scales. The rule of thumb is that a one MW solar energy plant with crystalline panels (about eighteen percent efficiency) would need approximately four acres of area, whereas thin film technologies (12% efficiency) would need ca. 6 acres.

5.2 Benefits of solar energy technologies

It is documented that nothing will compare with the energy potential of the sun. As solar energy is, in theory, ample enough, it can meet the world's electricity demands. Since solar energy is not only sustainable but also renewable, it is not necessary to think about the notion that solar energy might ultimately be exhausted. Global warming is characterized by destructive potential, therefore portending its harmful impact on the climate, environment (including animals and plants), and human health. Power plants (mostly coal-fired) are a major supply of greenhouse gases (GHG), that are liable for nearly 25% of all anthropogenic emissions, Jerez et al. (2015). Consequently, GHG emissions related to the generation of solar energy (including producing, installation, operation, and maintenance) are limited. The range of CO2 emission per kilowatt-h generated from coal, natural gas, and solar are calculable as 0.64~ 1.63, 0.27~0.91, and 0.03~0.09 kg (emission ratio of 18:9.5:1), respectively. As such, this comparison once more confirms the superior environmental friendliness of solar energy, among others. Accordingly, solar energy has become one of the foremost possible solutions to the present global warming crisis, which if left unregulated, may well be very costly with its potential ramifications. Thus, mitigating warming through the substitution of coal and gas-based power sources with solar energy can ultimately be environmentally, economically, and socially useful toward achieving sustainable development.

Solar energy is regarded as a non-polluting, reliable, and clean supply of energy. In contrast to other energy sources, its use is not accompanied with the discharge of harmful gases (e.g., oxides of C/N/S and/or volatile organic compounds (VOCs)) and particles (e.g., soot, soot, metals, and material (PM)). Such fossil fuel emissions from gas-fired power plants are indicted with regard to causing neurological harm, heart attacks, respiratory issues, cancer, etc. The replacement of fossil fuels with renewable energy may reduce premature mortality rates, lost workdays, and scale back the costs for healthcare. Furthermore, fossil fuel power plants need high quantities of water for their operation to exert a major influence on the current water shortage problems. A restricted accessibility to water during droughts and heat waves has reduced the generation of electricity by limiting its generation from power plants. On the hand, electricity generated from solar installations does not need water to operate; in addition, the existence of fuel by-products or the need for radioactive material waste storage is nonexistent.

When compared with fuel technologies that are primarily mechanized and capital intensive, solar energy technologies are thought to be being more labor-intensive. A positive facet of this notion is that solar technologies ought to improve job opportunities. On average, more jobs can be created per unit of electricity production with solar energy in contrast to fossil fuels. The solar business used around 208,859 staff within the USA on either a part-time or full-time basis for producing, installation, and sales. Within a year, a growth rate of 20.2% was reported. In addition, the industries liable for solar energy chain systems will also profit enormously, whereas some unrelated local businesses (due to a rise in shop and restaurants business hours) would conjointly profit from an overall increase in income, Ellabban et al. (2014). Moreover, local solar energy projects would keep money circulating within the local economy, hence saving a considerable quantity of money presently being used for the importation of fossil fuels from different locations. From an economic outlook, solar energy is beneficial in several ways because of tax incentives, elimination of electricity bills, increased property values, and high durability. The efficiency of solar energy technologies has increased dramatically in recent years and has been accompanied by an increasingly steady decline in costs, which are projected to drop even more.

6. Recommendations and areas of research

As earlier indicated, the one major challenge is the initial cost of solar systems which not affordable to many, especially in the remote areas of the country where most people don’t have access to electricity. The government and its sponsors can introduce discounts and layby schemes to prospective solar users. On policy and regulatory instability, measures can be put in place which promote the use of solar energy by incorporating energy usage incentives to customers. There is a need for the introduction of highly specialized research centers, which enable the development and production of cost-effective storage systems for solar energy to become a primary source of energy.

Training of systems designers and installers creates a broader platform of skilled manpower; hence some solar PV systems that are being installed can be optimized and more inefficient. Grid instability caused by the injection of solar energy in the national grid can be looked into at a broader scale by both the utility and private partners. For any network, proper system studies must be carried out to determine the appropriate position for grid integration. Generally, areas close the loads are the best but may also introduce some unwanted system losses in some cases.

Security of solar systems is also an area still requiring further research which is best suited for the location. Research still needs to be done in areas such as the integration of solar PV in the national grid without compromising its stability, cost-effective mechanism of energy storage as this is still a significant hurdle for the country to abandon conventional methods of electricity production. Improvement in the efficiency of the solar cell is also another area that needs to be researched on and efficient anti-vandalism mechanisms on solar power plants.

7. Conclusions and remarks

Solar PV projects successfully implemented will be a great benefit to both the national and personal development. With the move towards smart grids, the concepts of demand side management (DSM) can further be incorporated to meet world-class standards. As outlined in this study, Zimbabwe has great potential to meet the standards being set by developed countries in as far as PV systems are concerned. With determination and unit of purpose, the goal is achievable. Grid interlinked PV systems can also be a fundamental way in reducing the burden on the conventional power systems. A centralized monitoring and control center inform of a virtual power plant (VPP) can be set up for these grid interlinked systems. This further helps the participation in the electrical markets platform, thus having a direct effect on the price per kWh of energy. Additional revenue can be saved to improve the national grid network. Current studies show that properly connected PV systems can contribute significantly in network losses reduction, thus more profit to the utility. Well formulated regulations which are already in place and some which can be crafted to benefit the participators may be significant motivator and also leads to more job opportunities as the installations increase.

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