Feasibility study and development of a sustainable solar thermal power plant through utilization of mine wastelands

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\begin{abstract}
Southern Africa has been grappling with power shortages over the last decade due to reduced generating capacities from the region’s few hydroelectric power plants and depleted coal reserves for thermal power generation. This forced many companies to operate below capacity, although potential and resources abound. Research was carried out at one of Zimbabwe’s platinum mining and mineral processing companies to utilize the vast surrounding wastelands with abundant exposure to sunshine throughout the year to augment supplies from the national grid. A spreadsheet model was developed to derive various parameters such as beam radiation, thermal to electric plant efficiency and optimum temperature to determine the heat output incident on collectors. The System Advisor Model (SAM) was then used to simulate the values to determine the arrangement of collectors on the proposed solar thermal tower power plant as well as cost the project. Simulation of the model showed that the designed solar thermal plant can generate 30 MW, a sustainable and feasible output to supplement supplies from the national grid.
\end{abstract}

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1. Introduction

Despite having the bulk of Africa’s coal reserves and nuclear and uranium resources, Southern Africa suffers from a perennial power deficit dating back to the late 1990s [1] and follows very closely to Central Africa in terms of hydro resources and hydroelectric potential that remains untapped [2]. In a bid to strengthen regional integration and sharing of energy resources [3], the Southern African Development Community (SADC) member states established the Southern African Power Pool (SAPP) in 1995 as a cooperation of national electricity companies in Southern Africa to electricity trading between members with surpluses and those with deficits [4]. Although SAPP is well capitalized, it has not been able to overcome the persistent and growing power deficit due to a number of challenges such as; limited financial resources, absence of a dependable power supplies in the region and insufficient generation of power to meet the ever increasing demands [5]. SADC also lacked the skills for development due to the high attrition rate and migration of skilled engineers to greener pastures [6]. Power pools can only be sustained in regions with developed grid interconnections, reasonable generating capacities and a legal framework that they must adhere to [7]. Some of the mainland SADC countries such as Angola, Malawi and Tanzania are not connected to the SAPP regional grid to contribute to sustainable energy for all [8].

The perennial power deficit in Southern Africa was exacerbated by the global financial crisis that affected most parts of the world but more so for the region due to weak global interconnections and competitiveness [9]. This forced most SADC member states to introduce load shedding and in some cases, scheduled and unscheduled power cuts, the frequency of which has increased over the years as predicted by SAPP [9]. This led to the recommendation to fast track short term projects to get the region out of the crisis [10]. Although SADC earmarked and planned to commission new projects to generate an additional 3,000 MW in 2016 and then gradually increase this to an additional 30,000 MW by 2022 from the current 47,000 MW [8], projections and progress to date show that this may be difficult to achieve. These interventions also fell short and failed to match the rapid expansion of industrial and mining operations as well as the increased domestic consumption. Mining operations such as those at the case study company, with smelting and cominution of ore are energy intensive, requiring uninterrupted power supplies for their 24 hour operations. The power crisis affected SADC countries to different magnitudes depending on the countries’ macroeconomic fundamentals. Countries such as Zimbabwe were one of the worst affected due to the failure to service and maintain some of their equipment [11]. This resulted in a sharp drop from a generating capacity of 1,200 MW to 772 MW against a national demand of 2,200 MW, the deficit of which was imported at a regional tariff of 14c/kWh compared to the local tariff of 11c/kWh [11]. The financial crisis and power deficits also adversely affected businesses in Zimbabwe in that some companies had to scale down operations, resulting in laying off of staff and in some worst cases, liquidations and company closures. For those that remained afloat, capacity utilization dropped and some companies resorted to working odd hours in order to take advantage of the low tariff off-peak periods. Even though neighbouring countries with capacity to generate surplus may have been willing to trade their excess power under SAPP, the regional crisis forced some of these countries to preserve energy for their own consumption [11]. The case study was carried out at one of Zimbabwe’s platinum processing plants with the aim of developing a sustainable solar thermal power plant by utilizing the company’s vast wastelands that have abundant exposure to solar radiation throughout the year. This was carried out through a feasibility study, development and sizing of the plant for an output of 30 MW in order to augment supplies from the national grid. This was anticipated to enable the company’s metallurgical plant to operate uninterrupted, thus turning the problem of closed mines into an economic opportunity.

2. Background and literature review

Faced with dwindling coal reserves for thermal power generation, erratic rainfalls to maintain dam levels required for hydroelectric power generation and the increased demands for energy for domestic and industrial consumption, the world has increasingly pushed towards alternative sources of renewable energy for sustainable development [2]. Many countries with fossil fuel resources, such as Southern Africa and other parts of the world such as Iran, still relied heavily on thermal power generation using coal [12]. With improvements in technology and the wealth of information now available, solar energy has rapidly gained popularity despite high initial capital costs [2]. This has largely been driven not only by the increased demands for power but the abundance of renewable resources such as solar. Although many regions and countries continue to orient themselves towards renewable energy sufficiency, these cases remain...
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