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Design of Wind and PV-Solar Hybrid System for Tem Equipment in Geophysical Exploration for Geothermal Energy

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ABSTRACT

The research was tailored to optimize the design of a hybrid system that is powered by wind and solar energy in sustaining the power requirements of the Transient Electromagnetic Method (TEM) instrumentation. The issue addressed by the research was the unsustainability aspect of the batteries during TEM data collection. Therefore, the research tried to come up with an alternative that involved making power from wind and solar resources to power the TEM equipment. The research design began by doing a quantification analysis of both wind and solar resources in the geothermal area. In addition, a terrain and security analysis was done. Lastly, a hybrid system was designed considering its component specification that was governed by the wind and solar characteristics of the geothermal area under study. The sole aim was to solve issues faced with one form of green energy, geothermal energy, with other forms of green energy, wind and solar energy. The end result was the design of a revised final hybrid system that was able to sustain the power requirements of the TEM equipment during data collection in a geophysical survey with the available natural wind and solar resources in the Olkaria Geothermal field. From the analysis, it was evident that design of the hybrid system will primarily depend on the availability of the wind and solar resources in the area under study and the power requirements of the application being powered by the hybrid system.

Keywords : Hybridization, Viability, Optimization, Versatility, Transient Electromagnetic Method

I. INTRODUCTION

Since the inception of the electrical resistivity methods as a technique for surface exploration, researchers have devised several methods that can be used to power the instrumentation. Generators and batteries have been the predominant sources of electricity that are used to power the equipment. However, due to the extensive surface exploration exercises carried out in remote areas of a geothermal prospect, most geoscientists prefer the use of wet cell deep cycle batteries. Most of the electrical methods consume a lot of power from batteries that do not last long enough hence either the geoscientist has to carry a lot of batteries for backup or look for a conventional power to recharge the wet cell batteries. Both alternatives can be hectic and frustrating especially if the surface exploration survey is done in locales that are not near a charging location that is connected to the national grid. In that regard, there is an increasing need for more research to ensure that powering of the instrumentation is not a challenge by using a hybrid system powered by wind and solar energy.

More research has been done to test the versatility of the hybrid system with varied levels of success. Jankovich [1] with a team of experts designed hybrid system they called Twerly. The system made use of a Savonious Rotor and a Solar panel to power streetlights in South Africa. However, the project did not expand due to the expenses that were involved with the Savonious Rotor and its limited amount of wind power it would produce. Sanchez [2] with the Department of Electrical Engineering at the Barcelona College innovated another hybrid system using a Vertical Axis Wind Turbine and two solar panels. The aim was to power streetlights in Barcelona. However, the design was flawed due to shading caused by the wind turbine to the solar panels. It there necessitated for a redesign of the hybrid system to address the shading issue. In Kenya, along the Nairobi-Mombasa highway, the county government of Machakos installed a set of hybrid systems that has two solar panels and a Horizontal Axis Wind Turbine. The issue with the system was still shading on the solar panels by the wind turbine. Another issue was the poor security design of the project. This resulted to vandalism of the hybrid systems, NTV [3].

In that regard, the challenges faced by prior hybrid systems were considered by first quantifying the quality and quantity of wind and solar resources in the system installation prospect area. It was then followed by a terrain and securing design analysis of the area to determine areas of elevation and ensure the hybrid systems longevity respectively. Lastly, it involved designing a portable hybrid system that would sufficiently meet the power requirements of the Transient Electromagnetic Equipment during geophysical exploration. The above measures ensured that the versatility of the hybrid system could be tested in a geothermal setup while negating the challenges experienced by other systems.

II. METHODS AND MATERIAL

The materials needed for the design of the hybrid system included solar radiation and wind speeds of the geothermal field prospect to determine the quality and quantity of wind and solar resources. Analytical solar and wind formulas were needed to convert wind and solar resources to meaningful power through computations done by a scientific calculator. In addition, secondary data on the TEM equipment were needed to compute its power requirements. Lastly, the Terrain and Digital Elevation maps were used to station base locations for the hybrid system while considering elevated regions and setting up a security design.

A. Quality and Quantity of the Wind and Solar Resources in Olkaria

For the system to work and produce meaningful power, the natural resource in the area was supposed to be abundant. Since the proposed system would be self-sustained by solar and wind resources, an analysis of the wind resource and solar irradiance in the area was done. It was analyzed through the statistical approach of determining the monthly mean of the wind speeds and solar insolation parameters in a year. The aim was to determine the potential of the area in terms of abundance of wind and solar resources. However, a monthly analysis of the abundance of the resource was determined to recommend on the times of the year the system would be able to produce sufficient power to supply the TEM equipment. The data was obtained from the weather stations that were located along the Olkaria geothermal field prospect. If the natural resources were sufficient, the design of the hybrid system commenced.

B. Viability of the Hybrid System; Terrain and security design

The system required precise locations along the geothermal field prospect that were near ideal environment for it to effectively interact with the natural energy resources. In addition, the locations acted as base stations and were to be spread evenly along the geothermal field prospect. The idea was to ensure that the base stations would be accessible irrespective of the current location where the survey was conducted. Also, it was to ensure that there was maximum power output from the system to sustain the charging the TEM batteries. Hence to accomplish these, the Terrain Maps of the geothermal field prospect were useful in designing the base station locations.

However, the design took into consideration that the proposed system worked round the clock during the TEM survey hence the design of the security of the system was mandatory. Therefore, the base stations required security personnel co-existing in camp tents adjacent to the proposed hybrid system. The role of the personnel was to guard the system and often check the charging progress of the batteries as they charge during the night by the wind. Hence, the design of base stations was vital for the hybrid system to supply maximum power and to form sites for security points.

C. Hybrid System Design

The general design tried to determine the interface between the amount of wind and solar resources in the geothermal field and the power requirements of the TEM instrumentation during data collection. The interface was the hybrid system that converted the natural resources (solar and wind) to useful energy that was used to power the TEM instrumentation during data collection. Hence, the design considered both the cut-in and cut-out wind speeds and the solar insolation of the area. The wind and solar resource quality and quantity and were matched with the already available wind turbines and solar panels with their associated components in their circuitry found in the local market. The parameters under consideration included the closed Circuit Current I_{SC}, Open Circuit Voltage V_{OC}, Maximum Voltage V_{MAX}, Maximum Current I_{MAX}, Maximum Power, P_{MAX} for the solar panels to be used. In the case of wind turbines the specifications under consideration were cut-in and cut-out wind speeds, the maximum power output, the rotor diameter, type of wind turbine to be used and the weight of the turbine. The determination of the appropriate wind turbine and solar panel depended on the abundance of the natural resources. The higher the natural resource, the higher percentage of the energy generating component that constituted the proposed hybrid system. Such was determined after analysis of the wind speeds and solar irradiation obtained from weather stations available in the Olkaria geothermal field prospect. It should be noted that the design of the hybrid system was primarily governed by the power requirements of the TEM equipment during data collection. As such, the optimization of the proposed hybrid system was to meet TEM power requirements and be able to versatile enough to be used in a typical geothermal field prospect in terms of its portability. In addition, the versatility of the hybrid system was be done by determining the power output of the preliminary design, as shown in table 4.4, and checked whether it satisfied the power requirements of TEM equipment. The determination would govern the optimization of the proposed hybrid system to meet the power requirements of the TEM equipment.

D. System Justification

The economic justification of the hybrid system was done by performing the economic analysis of the various alternatives to meet the power requirements of the TEM equipment. The analysis was done using the Present Worth Analysis tool with an aim if justifying whether the use of the hybrid system was economically sound as compared with use of many batteries

III.RESULTS AND DISCUSSION

A. Quality and Quantity of the Wind and Solar Resources in Olkaria

Data used for the analysis of quality and quantity of the natural resources was obtained for the weather stations located in the Olkaria geothermal field. The wind speed trend, as shown in Table 4.1, indicated that during the day, the wind speeds were surprisingly higher (2.6-3.1m/s) than at night-time (1.3-2.0m/s). The solar insolation of Olkaria had values during the day range was 328-489W/m², as shown in Table 4.2. However, it was expected that there was no solar insolation at night (1800hrs-0600hrs).

Table 1: Monthly Average Quantities of Wind Speeds and Solar Radiation at Olkaria Geothermal Field

Month	Monthly Average Wind Speed (m/s)	Day-time [0600hrs-1800hrs] Average Wind Speed (m/s)	Night-time [1800hrs-0600hrs] Average Wind Speed (m/s)	Day-time [0600hrs-1800hrs] Average Solar Insolation (W/m²)	Night-time [1800hrs-0600hrs] Average Solar Irradiance (W/m²)
January	2.0815	2.793	1.370	488.76	0
February	2.203	2.796	1.610	466.56	0
March	2.391	2.970	1.812	481.93	0
April	2.482	3.198	1.766	382.49	0
May	2.569	3.078	2.060	383.79	0
June	2.395	3.160	1.630	328.29	0
July	2.274	2.867	1.680	351.61	0
August	2.365	3.074	1.655	403.15	0
September	2.229	2.980	1.478	456.03	0
October	2.116	2.900	1.331	388.79	0
November	1.969	2.63	1.308	341.05	0
December	2.090	2.790	1.389	387.78	0

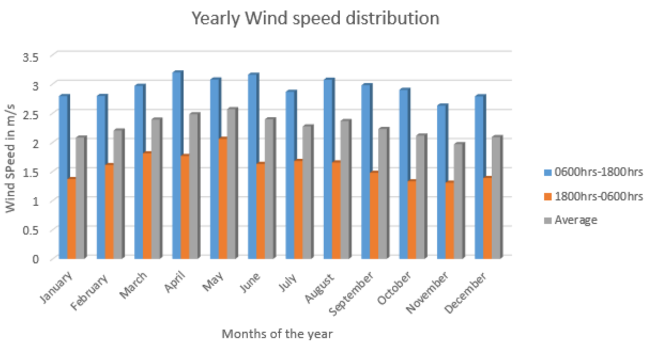

Fig. 1: Yearly wind speeds distribution of the monthly average quantities of wind speeds in the Olkaria geothermal field

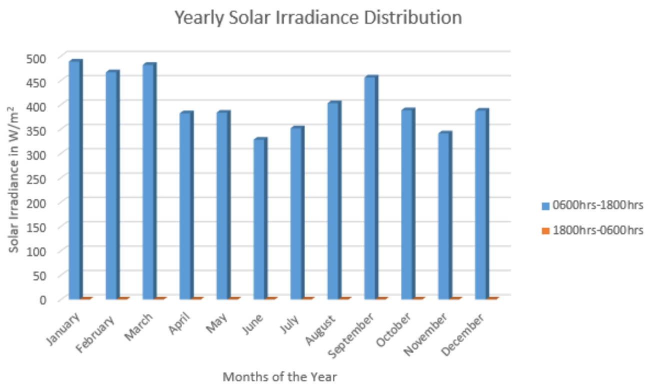

Fig. 2: Yearly Solar Irradiance distribution of the monthly average quantities of solar insolation in Olkaria geothermal field

Further analysis indicated that there was a negative correlation between the quality and quantity of wind and solar. Between the months of January and March in Trend 1, as shown in Figures 1 and 2, the trend indicated that the solar insolation was increasing and having the highest insolation values of the year, 488W/m². However, during the same period, the values of wind speeds where as low as 2.085m/s as compared to 2.5m/s experienced mid-year. In the months between April and September in trend 2, as shown in Tables and Figures 1 and 2, the quality and quantity of wind were the best during the year, 2.9-3.2m/s. However, during the same period, the solar insolation quality was the poorest, 328W/m². From October to December in trend 3, as shown in Figures 1 and 2, quality of wind speeds decreased (2.5m/s) and the value of solar insolation increases gradually to values approximately 350W/m².The various trends exhibited by the quality and quantity of the wind and solar resources were vital in determining whether the amount of energy from the natural resources can be used to produce sufficient electricity to supply the TEM equipment. In addition, from the wind speeds and solar insolation values, one can use them to determine the optimal hybrid system components that can work best in such environmental conditions.

B. Viability of the Hybrid System; Terrain and security design

An analysis of the hybrid system viability involved the use of the topographical Digital Elevation Maps as shown in Fig. 3. The analysis involved determining regions of high elevation using the contour lines in the Olkaria Geothermal field. Important to note was that before such analysis was done, the geothermal field was divided into different regions to aid in the terrain analysis of the field and also to ensure that the placement of all base stations was all inclusive in the geothermal field.

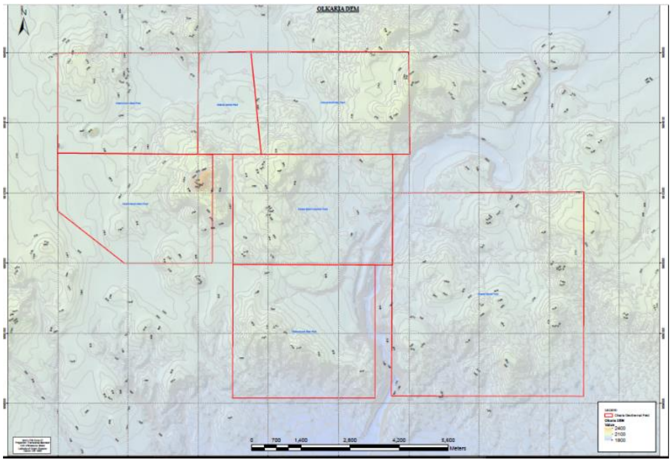

Fig.3: The subdivided Topographical Digital Elevation Model of Olkaria Geothermal Field

Some of the common observations made involved considering the contour line values whereby high contour values ranged between 2100-2450 m.a.s.l. as shown in Figure 3. Such regions were taken as viable sights for base station location since the idea is, the higher the terrain relative to its surroundings, the more interaction between the natural resources and the hybrid system in realizing the power requirements of the TEM equipment. The elevated regions in most of the parts of the geothermal field have belts that had varying orientations. However, in some low elevation regions, there are concentrated regions that have the highest elevation values of 3000 m.a.s.l. Such concentrated regions form the highest regions in the Olkaria geothermal field and form the best sites for the location of the base stations of the hybrid system. It should be noted that the base stations also formed sites for security. The reason was to cut cost of labor in that the individual guarding the hybrid system would also be responsible for monitoring the charging of batteries overnight.

C. Hybrid and Capacity system design

The hybrid and capacity design was done in accordance with the quality of wind and solar resources and the power requirements of TEM equipment. The aim was to design a hybrid system that could act as an interface of converting the energy of the natural resources in Olkaria to sufficient electricity that can sustain the power requirements of one sounding of the TEM equipment. As such, the capacity design of the system was done using the wind power and solar insolation equations vis a vis the different trends of the year as shown in Figures 1 and 2. First, an analysis of the power requirements of TEM was done and a comparison was made with the power capacity of the preliminary hybrid design as shown in the preceding subsections.

1.0 TEM Power Requirements

Data acquisition of TEM equipment requires 3 batteries. Each battery has a voltage of 12V and supplies power to TEM transmitter at a base load of 60Ah and are connected in series. Since most geothermal prospects have rough terrain, the survey involves data acquisition of one sounding. Complete data collection of one sounding takes a duration of 10 minutes depending on characteristics of the subsurface under survey. The turn over from one location of TEM data acquisition to another takes a duration of one and a half hours.

With the above parameters, the TEM power requirements was calculated as follows;

1. The total voltage of transmitting current round the TEM loop is given by 12V*3batteries= 36V since the battery connection is in series.
2. Determination of the amount of constant current consumed by the TEM configuration from the batteries during data collection; if in one hour, the rate of constant current supplied is 60A in one hour, therefore, in a duration of 10 minutes the amount of constant current supplied to TEM equipment during data collection is 10A.
3. Therefore, to determine the total power requirements of the TEM configuration in one sounding is given by; Power= (Total Voltage of Batteries)*(Total Constant Current). In that regard total TEM power requirements per sounding= (36V)*(10A) = 360W.

2.0 Power capacity of the preliminary hybrid system

2.1 Wind Power

An analysis of the quality and quantity of the wind resource indicates that wind speeds at Olkaria range between 1.3m/s to 3.2m/s. The average air density of Olkaria is 1.254kg/m^3 and area of a wind rotor with a cut-in wind speed of 1m/s (Blade radius of 1.558m) and a hub height of 11.558m in accordance to Park Wake's Model, Cheng and Zhu (2014). The efficiency of the wind turbine is 59.3%. The above parameters aids to quantify the amount of wind power available at Olkaria.

The above parameters are related to the wind power equation as follows;

$$P=0.5*\rho*A*V^3*C_P \quad (1)$$

Where P= Wind Power, A=area swept by rotor blades, V= velocity of wind, ρ= Air Density, C_P = power co-efficiency/ wind turbine efficiency.

2.2 Solar Power

The area of the solar panel to be used was 0.5696m^2 (solar panel dimensions= 64cm by 89cm) with the solar efficiency of 15%-20%. The angle of tilt is 28 ° and the coefficient of loses as 0.75 default value. The above parameters aided to quantify the capacity of solar power from solar irradiance at Olkaria Geothermal field. The number of solar panels used per unit of the preliminary hybrid system were two.
The above parameters will be related with the formula below to determine the month daily solar capacity.

$$E=A*r*H*PR \quad (2)$$

Where, E=Energy in kWh, A= Total Solar panel Area (m^2), r= Solar panel Efficiency, H= Average solar radiation on the tilted panels (W/m^2), PR= Coefficient of losses (0.75)

2.3 Total Wind and Solar Capacity of one unit of the preliminary hybrid system.

It involved the summation of the power capacities of wind and solar power per day as shown in Table 4. It was evident that, using the preliminary design, the power supplied by the system (87-141W), as shown in Table 4, was lower than the 360W required for one TEM sounding.

Therefore, this necessitated the testing of the versatility of the system by adjusting the variable components of the analysis such as increasing the number of turbines and area of the solar panels used.

2.4 Power Capacity of the revised final hybrid system.

It was evident that with the preliminary hybrid system design of two solar panels and a wind turbine could not satisfy the power requirements of one TEM sounding. In that regard, an analysis of the versatility of the design needed to be tested. Since wind power contribution to hybrid system capacity was high, there was need to add two other wind turbines in the preliminary design and reconfigure the layout of the hub tower to ensure optimal power generation by the wind turbines and solar panels. In addition, the area of the solar panel was increased from an area of 0.5696m^2 (panel dimension 0.64m by 0.89m) to an area of 1.2816m^2 (panel dimension of 0.96m by1.335m), as shown in Figure 5. Below are the final capacity of the optimized hybrid system.

Considering the power analysis from Table 5, it was clear that between the months of March to June, the revised hybrid system could provide sufficient to realize TEM power requirements (366-398)W. Between the months of September to February, the optimized hybrid system has lower power capacities (239-340)W. As such, exploration works can be done between the months of March to June every other year. However, in the event that there is need to perform TEM exploration works in any other different time period (September to February), an addition of another unit of the preliminary hybrid system (87-141) W could boost the power deficit of the optimized hybrid system. However, the cost implications would be dire during this period of the year.

The design of the hybrid system component specifications was governed by aspects such as portability, the compatibility of the electrical components in terms of voltage and power, and the wind speed (as low as 1m/s) and solar insolation characteristics (330-489W/m^2).

The revised final hybrid system passed all the above criteria hence further justifying the need for its adoption in addressing the unsustainability aspect of the geophysical wet cell batteries.

2.5 Wind and Solar Panel Specifications

Considering the quality and quantity of wind and solar resources and the meaning power extracted, Tables 6 and 7 indicates the component specifications. The equipment constituted the hybrid system that would work best in Olkaria Geothermal Field prospect in meeting the TEM power requirements.

2.6 Economic Justification of the Suggested Technology

The economic viability of the technology was done by performing an economic analysis of the use of many batteries alternative vis a vis the use of the hybrid system. The analysis made use of engineering economics tools such as the present worth analysis to choose an alternative.

Table 2: Average daily Wind Power in Olkaria Geothermal Field

Month	Day-time [0600hrs-1800hrs] Average Wind Speed (m/s)	Night-time [1800hrs-0600hrs] Average Wind Speed (m/s)	Day-time [0600hrs-1800hrs] Average Wind Power (Watts)	Night-time [1800hrs-0600hrs] Average Wind Power (Watts)	Average Total Wind Power per day (Watts)
January	2.793	1.370	61.80	7.294	69.09
February	2.796	1.610	61.99	11.84	73.82
March	2.970	1.812	74.31	16.88	91.18
April	3.198	1.766	92.76	15.62	108.38
May	3.078	2.060	82.71	24.79	107.5
June	3.160	1.630	89.50	12.28	101.78
July	2.867	1.680	66.84	13.44	80.28
August	3.074	1.655	82.39	12.86	95.25
September	2.980	1.478	75.06	9.156	84.21
October	2.900	1.331	69.17	6.689	75.86
November	2.63	1.308	51.59	6.345	57.94
December	2.790	1.389	61.6	7.602	69.20

Table 3: Average daily Solar Power in Olkaria Geothermal Field

Month	Day-time [0600hrs-1800hrs] Average Solar Irradiance (W/m²)	Total Solar Power per day (Watts)
January	488.76	41.76
February	466.56	39.84
March	481.93	41.18
April	382.49	32.68
May	383.79	32.8
June	328.29	28.04
July	351.61	30.04
August	403.15	34.44
September	456.03	38.96
October	388.79	33.2
November	341.05	29.12
December	387.78	33.12

Table 4: Total Daily Hybrid capacity of the preliminary hybrid system in Olkaria Geothermal Field

Month	Total Solar power on a daily basis (Watts)	Total Wind Power on a daily basis(Watts)	Total Capacity of the hybrid system on a daily basis (Watts)
January	41.76	69.09	110.85
February	39.84	73.82	113.66
March	41.18	91.18	132.36
April	32.68	108.38	141.06
May	32.8	107.5	140.3
June	28.04	101.78	129.82
July	30.04	80.28	110.68
August	34.44	95.25	129.69
September	38.96	84.21	123.17
October	33.2	75.86	109.06
November	29.12	57.94	87.06
December	33.12	69.20	102.32

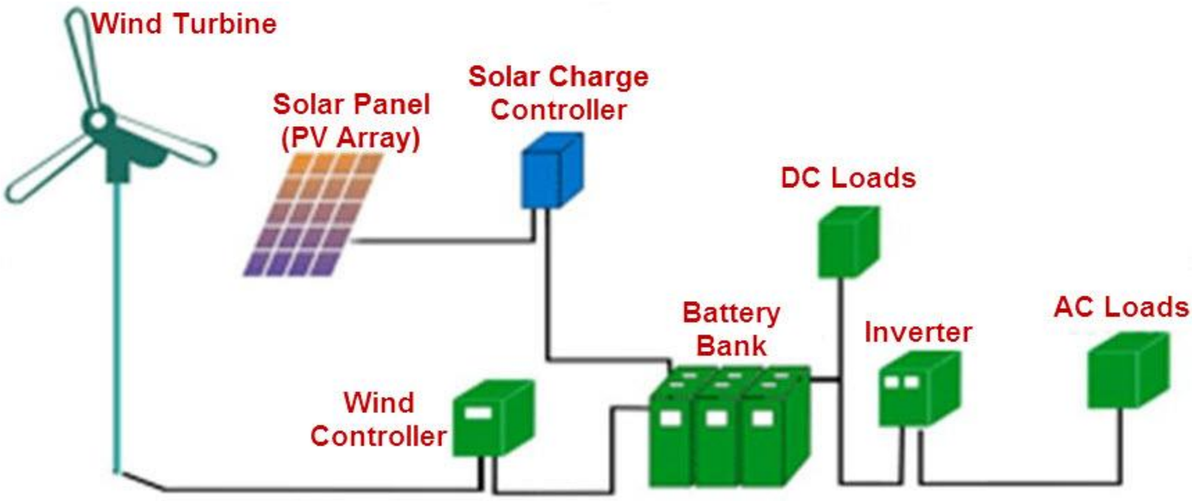

Figure 4: Schematic Diagram of the basic layout of the preliminary design of hybrid system.

Table 5: Average Revised Daily Solar Power in Olkaria Geothermal Field

Month	Day-time [0600hrs-1800hrs] Average Solar Irradiance (W/m²)	Total Revised Solar Power per day (Watts)	Total Revised Wind Power per day (Watts) [(power capacity of one turbine)*(3)]	Total Capacity of the Revised Final Hybrid System
January	488.76	93.96	207.27	301.23
February	466.56	89.69	221.46	311.15

March	481.93	92.65	273.54	366.19
April	382.49	73.52	325.14	398.66
May	383.79	73.78	322.50	396.28
June	328.29	63.16	305.34	368.5
July	351.61	67.59	240.84	308.43
August	403.15	77.50	285.75	363.25
September	456.03	87.67	252.63	340.3
October	388.79	74.74	227.58	302.32
November	341.05	65.56	173.82	239.38
December	387.78	74.54	207.60	282.14

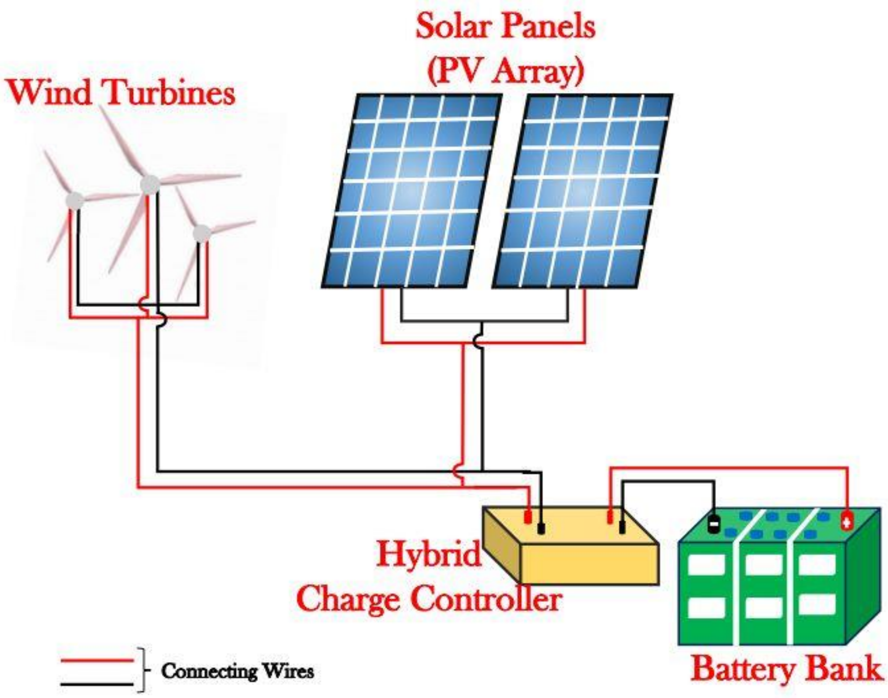

Fig. 5: Schematic Diagram of the basic layout of the revised final design of hybrid system

Table 6: Wind Turbine and its Components specifications

Characteristic	Description
Wind Turbine Model	The Wind Luce YWL-500
Start-up wind speed	1m/s
Cut-in Wind Speed	1.0-1.5m/s
Charging Wind Speed	1.5-2.5m/s
Rated Power	500W
Rated Wind Speed	12.5m/s
Survival Wind Speed	50m/s
Maximum Output	800W at 16m/s (generator without controller)
Braking System	Electromagnetic Braking System

Mass	17.5kg
Rotor Diameter	1.558m
Generator	Three Phase permanent magnet inner rotor coreless generator
Output	12V Battery Charging
Controller	Hybrid Controller (PV 500W + Wind 500W), with a LCD display and has a weight of 2kg
Blades	3 wooden blades, Polyurethane coating
Main Body	Aluminum, Acrylic Resin Paint
Wind Vane	Polycarbonate t=6

Table 7: Solar Panel and its Components specifications

Characteristic	**Description**
Model name	Mitsubishi, PV-MLE26OHD
Panel Dimension	0.96m*1.335m
Maximum Power Rating (Pmax)	260W
Open Circuit Voltage (VOC)	38.0V
Short Circuit Current (ISC)	8.98A
Module efficiency	15.7%-20.1%
Mass	20Kg

Table 8: Budget Estimate of Personnel involved in one TEM Sounding

Description	**No. of Personnel (a)**	**Period in Years (b)**	**Rate per Person per day [ksh] (c)**	**Total Cost [ksh] = a×(b×365 days)×c**
Team Leader	1	1	14,000	5,110,000
Surveyor	1	1	11,200	4,088,000
Geophysicist	1	1	11,200	4,088,000
Technician	2	1	11,200	4,088,000
Field Assistants	3	1	500	547,500
Luncheons	3	1	2,250	2,463,750
Total				**20,385,250**

Table 9: Cost Estimations of one Unit the Hybrid System Components

Component	Quantity	Cost per component [ksh]	Total [ksh]
Wind Turbine [The Wind Luce YWL-500]	3	400,000	1,200,000
Solar Panel [Mitsubishi, PV-MLE26OHD]	2	40,000	80,000
Hybrid Charge Controller	1	20,000	20,000
Total [ksh]		1,300,000	

2.6.1 Alternative 1: Use of additional batteries

In Table 9, the cost of carrying additional batteries by the field assistants is Ksh. 547,500 in a year. The cost incurred using this alternative has annual costs. Hence determining the present worth of the alternative made use of the following formula;

$$(P/A, i, n) = \frac{(1+i)^n - 1}{i(1+i)^n} \quad (3)$$

Where,

A is the annual cost (Ksh. 547,500)
i is the rate of return (14%)
n is the duration in years (20 years)

Therefore, the present worth of the use of extra battery alternative was –Ksh. 3.63M.

2.6.2 Alternative 2: Use of the hybrid system technology

From Table 4.10, the cost of buying all the components constituting the hybrid system costs approximately Ksh 1.3M. The costs involved in operating the hybrid system in a normal typical geothermal field was Ksh. 365,000 since it involved use of two field assistants. The revenue saved in this alternative was Ksh. 547,500 in form of additional labor costs incurred by alternative 1. Hence,

$$(P/A, i, n) = \frac{(1+i)^n - 1}{i(1+i)^n} \quad (4)$$

Where,

Initial cost (Ksh. 1.3M)

A is the annual cost (Ksh. 365,500) and annual revenue (Ksh. 547,500)

i is the rate of return (14%)
n is the duration in years (20 years)

The Net Present Worth of using the hybrid system alternative was –Ksh. 87,395.

The analysis was done over a duration of 20 years for the two alternatives. The duration was the life span of both wind turbines and solar panels used in the system. The rate of return (i) was obtained by setting the present worth to zero and equating it with the hybrid system cash flow and solving for i. The comparison of both alternatives over a time period of 20 years indicated that using the hybrid system (-Ksh. 87,395) alternative was cheaper than using additional batteries alternative (-Ksh. 3.63M). It, therefore, justified the need to change the current practice of using many batteries during a TEM geophysical survey. It proved that the adoption of the hybrid system was not only environmentally friendly but also economically justifiable option.

IV. CONCLUSION

From the analysis of wind and solar energy in Olkaria, a representative geothermal field along the Kenya rift, it is evident that the resources are abundant to meet power requirements of most of the geophysical methods. However, from the analysis of the power output of the preliminary design of the hybrid system, its power output did not meet the 360W power requirements of the TEM equipment. Through optimization of the preliminary design, it resulted to the revised final design, the power requirements of TEM were met (300W-400W) within the same Olkaria geothermal field station. It therefore implies that meeting power requirements of geophysical methods not only depends on the quality and quantity of wind and solar resources in the area but also the location of the hybrid system (base stations) and the design of the hybrid system.

However, further research suggestions would aid in completion of the project. For instance, there is need to test the versatility of the hybrid system in other geothermal field prospects not only along the Kenyan Rift but also in other geothermal prospects in the world. In addition, optimization of the hybrid system should be done to check whether the hybrid system can meet the power requirements of all the geophysical methods during a survey.

V. REFERENCES

[1] Arjun A. K., A. S. (2013). Micro-Hybrid Power Systems – A Feasibility Study. *Journal of Clean Energy Technologies, Vol. 1*, pp27-32.

[2] Sanchez. (2014). Evolution of the energy consumed by street lighting in Spain estimated with DMSP-OLS data. *J. Quant. Spectrosc.Radiat. Transf*, pp 109-117.

[3] Kenya, N. (2017, November Sunday). *NTV news*. Retrieved from News and Politics: https://ntv.nation.co.ke/news/2720124-4203254-vnyf9g/index.html

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