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Design of 50 MW Grid Connected Solar Photovoltaic Power Plant in Dongola City, Sudan

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Abstract:- During unfair war in Sudan breeze up since April 2023, big energy generation shortage took place in Sudanese National Grid (SNG). The power distribution company fails to supply the required demands for residence and commercial consumers with sustainable energy. Power interruptions during day and night is big headache for residential and commercial subscribers. Due to dependence on thermal generation, in war time the priority is for food products so furnace importing stopped which led to the noticeable shortage in generation. In the recent years renewable energy resources have gained much importance due to friendly environmental and climate enhancements. Beside this the needs to reliable energy supply became urgent. The huge energy source like the sun helps in afford sustainable and economic supply. Dongola city in Sudan has a dry climate so it receives big quantity of solar energy. The average solar energy about 4.97kwh/m^2/day is received. The other types of renewable power like wind energy is also available for construction. PV syst, PV-GIS and MATLAB are the simulation software applied for this project.

Keywords:- *Cell Orientation, Capacity Utilization, Module Temperature, Power Losses, Performance Ratio, Baterries Discharge Equalization.*

I. INTRODUCTION

The contribution of Photovoltaic (PV) technologies in local and National power grids stability became noticeable in last decade. Sudanese government through ministry of energy and Minerals begun big steps towards renewable energies projects before this unfair war. Sudan with such diversity in weather and big territory owned suitable conditions for renewable energy projects. The proposed study was conducted, which represents one of the renewable energy resources, in north state, Dongola City, Sudan to prove the appropriateness of sustainability and provided base line research on the specific applications. Grid-connected PV power systems contain solar panels, and other accessories and equipment contribute for generation the solar energy with good efficiency and they are having low energy storage losses.

The PV-systems, as grid-connected supplies the excess power and after that share the load with utility grid. The ratio of the shadow during the day is characterized by solar altitude and solar azimuth angles that are easily determined from the position and irradiation inclination angles. The quantity of solar shine, and the Sun's inclination angles must be taken timely during the day to design optimal HPS project [1]. The net generated power of the PV power system relays on the appropriate panels position and current equalization technique. This paper proposes a 50 MW Grid-Connected Solar PV array to enhance the grid reliability and efficient power supply. The way of how Solar PV maximum output power (MPP) related the environmental factors was studied [2]. This era an opportunity exists to use renewable resources in Sudan the solar radiation resource meets high electricity demand specially during current unfair war. This paper describes the procedure of designing a 50 MW of PV solar power plant on the conditions of Dongola City, Sudan. Sudan Located in northeastern Africa, has complex weather varies from very hot, to hot, moderate cool and rainy as depicted in Figure 1. The principal climatic aspects affecting building construction and comfort are solar radiation, temperature, humidity and wind speed [3]. Sudan's National Grid (SNG) during the current unfair war suffered from instability and frequent black out. At present situation the electricity generating methods consists of thermal power and hydropower as main generating plants [4,5].

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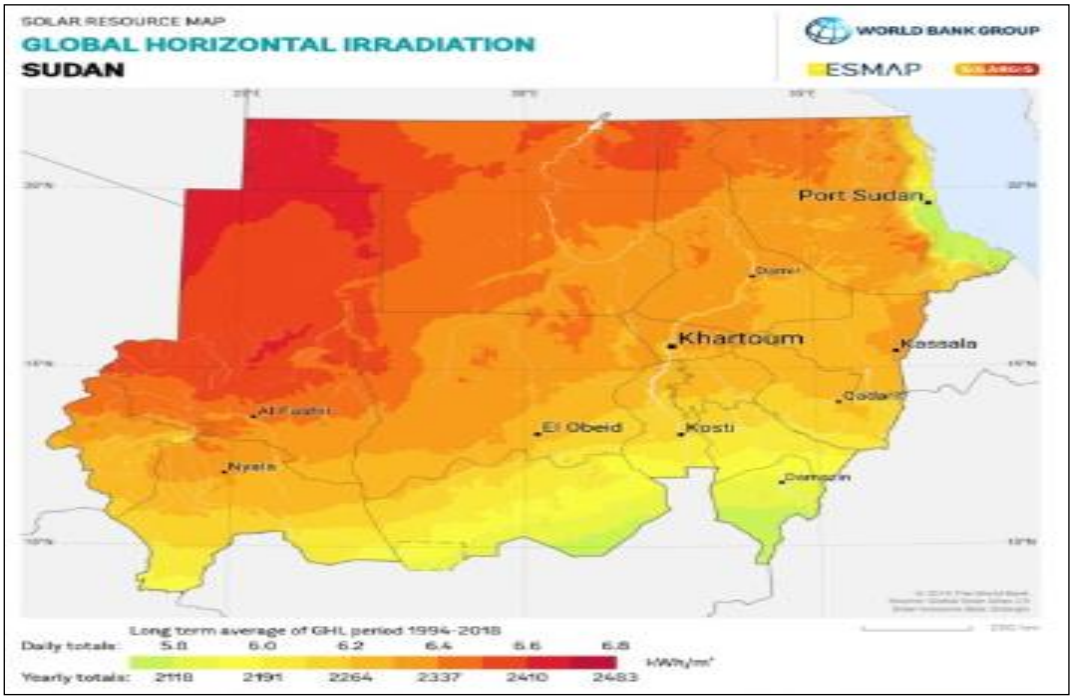

Fig1. Global Horizontal Irradiation Map.

Conventional electrical generation in Sudan operates by petroleum produces about 50% of the SNG total power.

II. HYBRID POWER SYSTEMS

Grid connected renewable power systems are kind of Hybrid Power Systems (HPSs) [6]. Inserting wind mill and solar power systems in SNG will decrease the pollution and ozone damaging problems and enhance grid sustainability. Hybrid renewable sources will lead to reliable and sustainable power supply. This HPS will contribute to the SNG with clear injected power with synchronized frequency will not affect PS stability and sustainability. In some other cases, renewable energy sources to complement each other they constructed in a hybrid way to the national grid l [7]. The mixing of a weighty share of different renewable sources into country grids involves a proper analytical method. The current paper describes the construction of a 50 MW solar photovoltaic power plant using the most recent conditions, and land availability at Dongola City. The designed HPS combines numerous harvestings means to increase energy creation. Figure 2 shows the main components of the proposed HPS.

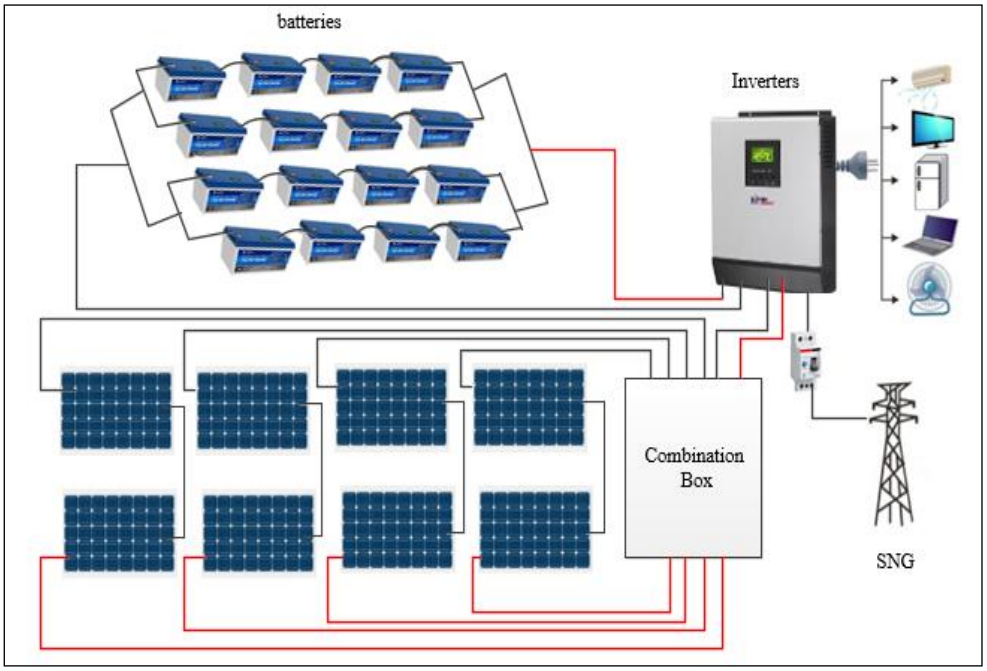

Fig.2 The Hybrid Power System main blocks

III. PLANNING AND LOCATION SITES

Selection the suitable location to install renewable power system such as PV is an important issue. Choosing such location depends on several environmental factors [8]. The nominated place should augment and expand the power supplying process. To inject the generated power to NG power system planners, have to select a place to install the renewable energy power plants with proper conditions [9]. It is very vital to let the renewable and clear power stations nearby load centers in crowded cities like Khartoum, and power consuming areas out of national electricity network. All the essential measures for a fruitful Renewable Power Supply (RPS) application is suitable to be constructed in Sudan, is needed to meet energy demand during this hard period. The economic situation is still very weak, so the power sector must encourage solar energy application in the infancy stage often due to the factors for sustainability 10]. The Sudanese Energy and Mineral Ministry policies should be focused on declaration of economic energy supply, with good reliability, and environment friendly power supplies. Solar energy and Wind Power System both are interesting. Renewable energy power systems development is fruitful and profitable project. Governments should encourage universities, research centers and by administration within relevant ministries to take part in designing such projects [11].

The Ministry of Power and Mineral made a plan to meet the increasing load demand for developing industries. The expected additional generation is 20GW. In 2030 the net renewable sources power generation will increased up to 20 GW. Environment friendly power supplies can deliver 80% of the SNG power lack. Solar power systems have identification characteristics, which make it highly attractive as main and environment friendly energy resource. It is based upon an uninterruptedly renewable power resource which cannot be exhausted and not an issue of political regulation laws. The position of Sudan country as part of big Sahara and tropical area enhances the truth of big solar potential [12]. The regular temperature and sun shine varieties from 42 to 50°C. The average solar irradiation is an important factor for Solar power systems construction, in Sudan country the solar irradiation is around 6.1 kWh/m2/day, indicating a high potential for solar energy use. Employment and translating the Solar PV arrays power system required operative and economical power generation technologies. These advanced power generation technologies must possess an excellent technical characteristics with reasonable and low cost. It very important in term of economic that the cost of generated power to compete the cost of power generated by fossil energy and to treat the grid faults [13].

The designed project aims to create reliable HPS (PV array connected to NG) at Sudan's Northern State. In year 2020 Northern state has witnessed a construction of experimental wind power plant. The scope of HPS project shall include area selection for solar panels (about 235691 m^2), soil examination, design manufacturing, supply, transportation of material to the site, installation and commissioning of elated equipment's, including the related civil works and site supervision [14]. The Dongola City, located in the northern part of the Republic of Sudan around 460 km to the north of Khartoum the capital city. The PV Array manufactured by Jinkosolar is installed as in Figure 3.

Fig. 3 Jinko solar model JKM580M-7RL4-V, 580Wp/unit

The PV array in the field is kept in optimum orientation to the latitude of the corresponding location to get maximum solar radiation with Tilt/Azimuth 15 / 0°. Installed PV array and Inverter Characteristics are given in Table 1 and Table 2. Inverter convers DC power into AC power. The output of the inverter is synchronized automatically with same voltage and frequency as that of SNG.

Table 1. PV Array Characteristics

Manufacturer	**Jinkosolar**
Model	JKM580M-7RL4-V
Unit Nominal Power	580 Wp
Number of PV modules	86205 units
V MPP	603 V
I MPP	75695 A
P MPP	45.62 MWp
Total PV power	49999 KWp

Table 2. Inverter Characteristics

Manufacturer	**Hyundai**
Model	HPC-500HL-EU
Unit Nominal Power	500 kWac
Number of inverters	74 units
Total power	37000 kWac
Operating voltage	450-820 V
Pnom ratio AC:DC	1.35

IV. PERFORMANCE ANALYSIS

The capacity factor was used to calculate how much energy the solar PV plant produces on sunny and overcast days versus the maximum amount of energy it could theoretically produce if it operated at full capacity on that same day. The obtained results of designed PV array power system analyzed in this section. Table 3. shows PVsyst annual results PV array specifications and constraints.

Table 3. The Annual Results Obtained from PV-SYS

	Global Horizontal Irradiation	**Horizontal diffuse irradiation**	**(AT) Ambient Temperature**	**Global incident in coll. plane**	**Effective Global, corr. for shadings**	**Effective Energy**	**Net Energy**	**(PR) Performance Ratio**
January	153.2	43.2	21.10	184.1	180.7	7934	7753	0.842
February	154.2	54.1	23.20	174.3	171.5	7402	7231	0.830
March	196.3	71.1	27.25	209.5	205.8	8679	8476	0.809
April	202.1	83.2	31.19	203.2	199.3	8353	8161	0.803
May	206.7	94.8	34.82	198.8	194.6	8133	7948	0.800
June	203.6	93.4	36.00	192.1	188.0	7838	7659	0.797
July	201.5	97.0	36.34	192.0	187.9	7847	7668	0.799
August	185.0	100.8	36.38	182.6	178.9	7471	7300	0.800
September	171.5	84.8	35.40	177.8	174.2	7284	7116	0.801
October	162.8	79.3	32.82	177.6	174.2	7377	7208	0.812
November	144.6	54.9	26.85	169.1	166.0	7188	7022	0.831
December	137.5	49.8	22.69	165.9	162.6	7180	7018	0.846
Year	2119.1	906.3	30.37	2227.0	2183.6	92686	90561	0.813

Usually, the designed Performance Ratio is around 80% due to the unavoidable losses during operation. The following Figure. 4. shows the performance ratio (PR) of the PV plant of 50 MW using mono crystalline photovoltaic system. The PV plant monthly performance ratio is around 81.3 %, which is considered a valuable amount since the system enhancing the SNG.

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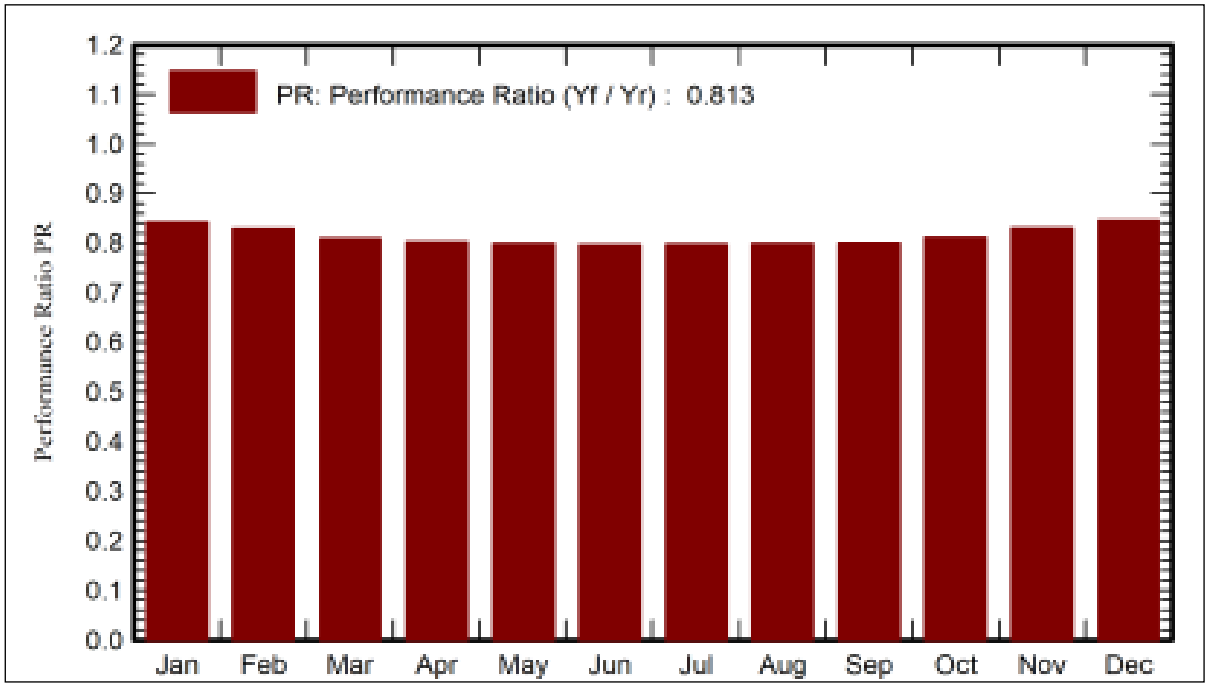

Fig. 4 Performance Ratio

The performance ratio is a quality measuring factor that measures the quality of a PV plant. It describes the relationship between the theoretical and actual energy outputs of the PV plant. The PR shows the energy after deduction of energy consumption and losses. Performance analysis of designed PV solar grid-connected plant enhances operating and maintenance of SNG. A 50 MW PV grid-connected PS commissioned at Dongola City is one of largest solar power plants in the country. The various types of power losses (temperature, internal network, power electronics, grid. The designed PV power system clearly shows the effect of temperature variation on the performance of photovoltaic modules on a daily and yearly basis. The efficiency is more sensitive to temperature than the solar irradiation. During morning time, the efficiency of the plant is high until the afternoon and then starting to decrease to sunset. connected) and simulation values obtained from PV syst and PV-GIS software. The inverter efficiency appropriately called as conversion efficiency is given by the ratio of AC power to DC.

The inverter to the DC power generated by the PV array system. The instantaneous inverter efficiency is given by, PAC/PDC. System efficiency. The instantaneous daily system efficiency is given as PV module efficiency multiplied by inverter efficiency.

V. CONCLUSION

The designed PV 50MW injected to the grid in Dongola City is a good choice for sustainable power supply. The solar irradiation level ensures the successful power plant running. The given designs involved the power plant arrangement and all the electrical drawings with electrical typical measures for beneficial execution. PVsyst program used in this project to trace the designed power system efficiency and generation calculation was done which comes out to be 70- 80% for the whole year working. Also, after studying whole plant and its procedure to develop it, some of the research study was done along with this design which can be helpful in future to increase the efficiency of any solar plant. The Performance of solar cells in different places is dependent on the difference of the environmental conditions and their output parameters in mother country and the working one. This performance parameters such as output voltage, current, power, and fill factor vary by temperature and environmental conditions. The executed experimental results proved that, the most significant changed by temperature is voltage which decreases with increasing temperature while output current slightly increase by temperature.

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