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Feasibility Study of a Solar Farm Project with an Executive Approach

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***Abstract*—**Since 2015, a new approach and policy regarding energy resources protection and using renewable energies has been started in Iran which was developing new projects. Investigating about the feasibility study of these new projects helped to figure out five steps to prepare an executive feasibility study of the concerned projects, which are proper site selections, authorizations, design and simulation, economic study and programming, respectively. The results were interesting and essential for decision makers and investors to start implementing of these projects in reliable condition. The research is obtained through collection and study of the project's documents as well as recalculation to review conformity of the results with GIS data and the technical information of the bidders. In this paper, it is attempted to describe the result of the performed research by describing the five steps as an executive methodology, for preparing a feasible study of installing a 10 MW – solar farm project. The corresponding results of the research also help decision makers to start similar projects is explained in this paper as follows: selecting the best location for the concerned PV plant, reliable and safe conditions for investment and the required authorizations to start implementing the solar farm project in the concerned region, selecting suitable component to achieve the best possible performance for the plant, economic profit of the investment, proper programming to implement the project on time.

***Keywords*—**Solar farm, solar energy, execution of PV power plant, PV power plant, feasibility study.

I. Introduction

THE scarcity of fossil fuel resources, predicted to run out in the near future, and constant rise in price besides increasing world population as well as promotion of living standards has forced governments to find and utilize alternative fuels, clean energies and waste energy recovery technologies at the same time. Since 2015, in Iran, the government has implemented preventive laws alongside motivate legislations in order to encourage fossil fuel consumers to use alternative or clean energy resources, recovering waste heat and utilizing power generation systems. The high potential of solar energy absorption in Iran, due to the country's geographic location and environmental condition, places solar energy photovoltaic systems at the centre of attention and the best approach for using renewable energy in the country. It was the reason to have 10 solar farm projects executed in Iran (around 65 MWP) from 2014 to 2017. This is according to the GIS Photovoltaic power production in Iran, which is shown in the following map (Fig. 1).

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Investigating and being acquainted with the remarkable and active related projects in Iran, such as the recovery of waste heats to produce power (WHRPG) - using Refused Derive Fuel (RDF) as alternative fuel in cement kilns - installation of PV power plants (solar farms) which are all very useful and effective in protecting fossil fuel resources and achieving a clean environment, have been the mainspring of preparing this paper to introduce a methodology of preparing the required feasible study of a solar farm project for decision makers with an executive approach to implement the concerned projects by elaborating a sample project.

The selected project for this paper is located in Khash, Sistan Balouchestan (south east of Iran), it is aimed to produce the 10 MWP electricity and be connected to a 20 KV grid.

II. Selection of the Site Location

The first and a vital step in the success of a solar power plant is selecting a proper site location for which the solar power absorption should be observed. Meteorological conditions should be considered and the following selection indexes should be investigated and studied:

i. Possibility of ownership of the land
ii. Location with proper level
iii. Access to appropriate access road
iv. Safety and security of the location
v. Possibility of extension in the future
vi. Access to the electrical grid and substation
vii. Access to infrastructure

For the considered 10MW power plant, about 20 hectares of the land is required. According to the World Bank GIS for the considered region, which is Sistan Baluchestan Province, Khash County, located in the south eastern regions of Zahedan city, the photovoltaic potential is expected to be around 1972 KWh/KWP [1]. Meteorological conditions of the selected region, indicated in Table I, observing the world bank GIS data should be considered simultaneously to estimate the accurate irradiation predictions for design purpose [2].

In the considered region, five locations are nominated and studied. To select the most suitable location, selection indexes (i to vii) are compared and the best location was selected [2]. Selection indexes of the considered location besides the GPS coordination of four corners of the selected the lands are mentioned in Tables II and III.

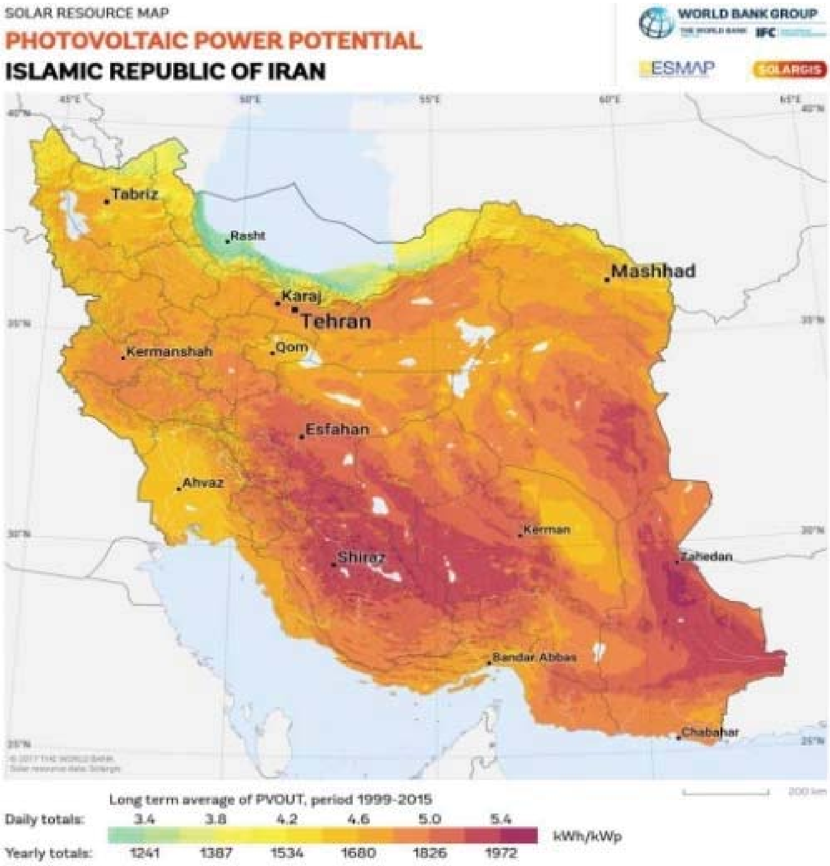

Fig. 1 Iran's Photovoltaic power absorption in GIS

TABLE I
METEOROLOGICAL DATA OF THE LOCATION

Months	Sunny hours	Ave. Temp	Wind		
	Hours	C	m/s Ave	m/s max	Direction
Mar	9.3	18.6	14.2	25	310
Apr	10.5	24.5	13.6	19	290
May	10.9	28.5	14.4	24	70
Jun	10.8	30.4	14	21	290
Jul	10.8	29.3	13.7	19	330
Aug	10.7	26.3	12.8	20	130
Sep	10.1	21.5	10.9	19	250
Oct	9	16.5	10.5	17	360
Nov	7.9	11.4	11.6	18	220
Dec	7.4	8.9	12.5	18	250
Jan	7.7	10.1	14.7	27	230
Feb	8.1	14.1	14.6	23	200

TABLE II
SELECTION INDEXES OF THE LOCATION

Location Name	Selection Index	Result
Selected Location	.i	No private owner
	.ii	Flat
	.iii	Just beside
	.iv	Behind military court
	.v	Free land around
	.vi	3km to substation-grid line just beside
	.vii	Against industry zone

TABLE III
COORDINATION OF LOCATION CORNERS

Point Number	Latitude (Northing)	Longitude (Easting)
1	28.267	61.128
2	28.269	61.131
3	28.265	61.135
4	28.263	61.132

Using World Bank GIS [1], estimated solar indexes for the selected location are indicated in Table IV.

TABLE IV
PHOTOVOLTAIC INDEXES OF LOCATION

Solar resources	Amount
Global horizontal irrad. – kwh/ sq. m	2264
Direct normal irrad. – kwh / sq. m	2374
Diffuse horizontal irrad. – kwh/sq. m	744
Global tilted irrad. – kwh/sq. m	2515

III. REQUIRED AUTHORIZATION

The main concern of investors in regard to solar farm projects is selling the yielded power of the plant. In response to this concern, the Power Purchase Agreement (PPA) offered by the Ministry of Energy of Iran (SATBA) [5] is the best solution. Through this solution, the purchasing of the produced power is guaranteed for 20 years. Regulation for pricing the solar energy production is legalized and mentioned in the contract and it depends on the capacity of the solar plant, less and equal to 20 MWP, less and equal to 100 MWP [2], and more than 100 KWP. Base prices for purchase are categorized in the PPA and 8.48% as the increasing rate factor of the base price is predicted for each year [5]. The increase rate factor comes from a formula in which the foreign exchange rate and electricity price have considered to calculate the increase rate of the base price annually.

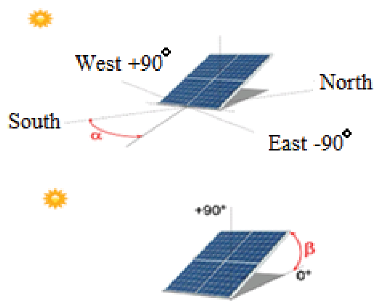

Fig. 2 PV modules facing data. Estimated PV output: 19398 MWh/year, Module facing data according to Fig. 2: Azimuth (α) = 180° (facing to south), Tilted (β) = 30° (to horizon)

Payments to investors are considered to be through a Letter of Credit (L/C). These are all provisions to encourage and convince investors to perform this enterprise. According to the regulations, three authorizations are required for signing the PPA as follows [5].

A. Installation License

SATBA is responsible to issue the license. The applicant is expected to make the proper site selection, perform a prelaminar design and specify the technical specifications for the solar system elements, all of which must be accepted and approved by SATBA to issue the license.

B. Grid Connection Plan

Local Electric power Distribution Company (LEDC) is responsible to approve the grid connection plan for the considered solar farm and indicate how the produced power of the solar farm would be distributed and connected to 20 KV by the grid. A grid connection plan would be prepared by the applicant who is introduced by SATBA to LEDC. The grid connection plan should be approved by LEDC.

C. Environmental Permission

The local organization of the Iranian Department of Environmental (IDE) is responsible to issue the environmental permission for installation of the PV plant. According to the installation license, SATBA asks IDE to issue the required environmental permission. After taking the aforementioned authorizations, the applicant is supposed to follow up the PPA through coordination with SATBA. It is essential to attach the considered technical specifications of the selected solar system components to the PPA. So, in parallel to follow up the PPA, it is necessary to design and select the technology and attach the optimized and feasible choices. The design is the subject of the next step. This means that step II and step III would be performed in parallel.

IV. Design and Simulation

It is essential to select and assess the technical specifications of PV plant components in order to achieve the highest capacity and the best performance of the plant. Photovoltaic panels (PV), inverters and medium voltage units (MVU) are the main components of a solar farm for which there are a lot of technologies and brands in the market. Technology selection of the main part of the solar farm would be according to experience, market survey and design of PV's system [2]. The performance of the considered components of the PV system could be assessed by using PVSYST software (it calculates annual yield power of PV plant using technical specification of the PV system) [2]. For the 10 MWP the solar farm in this study, the selected technical specifications of components are mentioned in Table V [6], [7].

TABLE V
Photovoltaic Indexes of Location

Components	Numbers	Technical Spec.
PV's	37576	270 w - %16.6 eff.
Inverter	5	2000 kw
MVU	4	2500 kw

A. Designed Arrangement

According to PVSYST the annual product of the solar farm with selected specifications would be 19838 MWh/year. The input parameters data to PVSYST are listed as:

1. PV's

Orientation: (tilt) = 30 & Azimuth=180
Number of PV's = 37576
Total module area = 61132 m^2
Capacity = 270W - Einnova Solarline
Efficiency = 16.6%

2. Inverter

Number of modules = 5
Capacity = 2000KW – Helios
Voltage = 500 – 820
The output of simulation by PVSYST is shown in Table VI.

TABLE VI
New Simulation Variant Balance and Main Result

Months	GlobHor Kwh/m^2	GlobInc Kwh/m^2	E_Gridd Mwh	PR
Jan	129.9	191.3	1655	0.853
Feb	134.7	177.4	1505	0.837
Mar	175.5	202.5	1680	0.817
Apr	190.5	194.2	1562	0.793
May	234.4	213.7	1676	0.773
Jun	233.0	201.8	1570	0.767
Jul	233.0	206.1	1593	0.762
Aug	230.1	223.2	1732	0.765
Sep	211.1	234.1	1844	0.776
Oct	174.9	220.5	1785	0.798
Nov	138.7	200.8	1681	0.825
Dec	120.0	181.0	1555	0.847
Year	2205.8	2446.5	19838	0.799

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Performance ratio (PR) is one of the most important variables for evaluating the efficiency of a PV plant. PR is ratio of possible actual and theoretical output energy of the plant. High performance PV plants have a PR near 80%. For corresponding plant with selected technology and technical specification of PV's, PR is equal to 79.9% which means 20.1% of incident irradiation would not be converted to output. To calculate the performance ratio the following formula can be used.

$$PR = \frac{E_{Grid}(\text{according to loss diagram})}{\text{GlobInc} \times \text{total are of PVs}} \quad (1)$$

$$\text{Example – January: } \frac{19838000}{2446.5 \times 61132 \times 16.6\%} = 0.799$$

The loss diagram over the whole year (according to the output report of PVSYST) gives a better understanding about the effect of losses on Global Irradiation (GlobHor), which eventually reaches to Energy injected to Grid (E_Grid), as shown in Fig. 3.

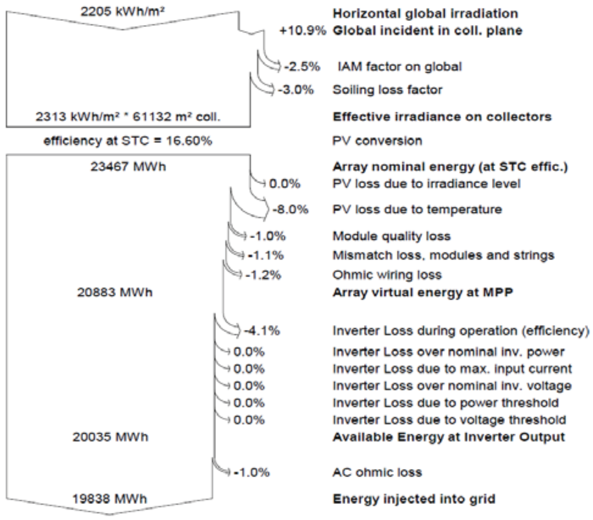

Fig. 3 Loss diagram of the whole year

V. Feasibility Study

The feasibility study result of a project is determinative to execute the project. It is including evaluation of the economic and technical parts of the concerned project. So we do perform the evaluations for the 10 MWP solar farm project to reach the conclusion. The yield product of the plant for the first year of operation would be 19838 MWP, according to step 2 [3], [6], [7], with a performance wane rate of 1% (annual decreasing rate of PV's performance) over the plant lifetime, which is considered to be 20 years. Required investment for installation of a 10 MWP solar farm would be 11,750,000 Euros through an EPC contract, besides an operation and maintenance cost of 60,000 Euros/year for the plant (according to bidders). The output selling price of the plant, according to the PPA, would be 0.1 Euros/KW for the first year after signing the PPA with an increase rate of 8.478% over the PPA time (20 years) [5]. The aforementioned factors are the bases of estimating the income and feasibility study of the project execution, which are the main concerns of the investor. To digest the project execution economically COMFAR III software [4] is utilized with the following input data [5]-[8]:

Investment budget = **11750000** Euros
Financial source = **85%** loan
Cost of financial source = **4**%
Operation costs = **60000** Euros/year
Inflation rate = **10**%
Discounting rate = **15**%
Interest rate for investors = **18**%
Yield product = **19838** MWh/year
Annual performance wane rate = **1**%
Depreciation rate = **10**% /year – drop-down
Base selling price of PPA = **0.1** euros/KW
Increase rate of PPA the price = **8.478**%/year
Duration of Installation = **18** months
Duration for operation = **20** years

Investors are very curious about the economic condition of their investment. COMFAR III reports applicable and meaningful economical indexes of the project. The most important indexes are: internal rate of return (IRR), Normal payback and Dynamic payback which are described as follows.

1) Internal rate of return (IRR) indicates the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero. Internal rate of return is used to evaluate the attractiveness of a project or investment. The more IRR means the more feasible the project. Projects with IRR greater than 20% are suitable and attractive for investors [2].
2) Normal payback indicates the period of time required to recoup the funds expended in an investment or to reach the break-even point.
3) Dynamic payback indicates the period after which the capital invested has been recovered by the discounted net cash inflows from the project. Running COMFAR III, the result of the considered economic indexes for our 10MWP project with the selected technical specifications of the components is indicated in Table VII.

TABLE VII
Using Fixed PV's Mounting System

COMFAR III economic index	Result
Internal Rate of Return (IRR)	19.5%
Normal payback – years	5.61
Dynamic Payback – years	10.8

If we could improve the IRR, we could have had more feasible projects. One way to increase IRR is to increase the income of the plant, for which, improving the current yield product of the plant (19,838 MWh/year) would be an effective solution. Utilizing a tracker system which always and automatically keeps facing the PV's directly to solar irradiation could improve the yield product of the plant about 19% (23,000 MWh/y) [8]; although, it is necessary to increase the investment budget by about 9% (12,774,800 Euros). Running COMFAR III again for the new conditions using the tracking system, the result of the considered economic indexes for the studied 10MWP project are shown in Table VIII.

TABLE VIII
USING TRACKING SYSTEM FOR PV'S

COMFAR III economic index	Result
Internal Rate of Return (IRR)	22.89%
Normal payback – years	5.97
Dynamic payback – years	8.87

VI. EXECUTION PROGRAM

Performing each of the described steps takes time. To avoid wasting time and to finish the project on time, it is essential to prepare a time schedule in which all activities for each step should be considered in the term of starting point and duration as well as priority or required predecessors. It would be better to divide the whole project into two stages. The first stage is the development part which includes step 1 to step 4, while the second stage is execution part which includes the site preparation, detail design, equipment supply, civil works, erection works, and finally, the last stage is the start-up of the plant. Consideration of two mentioned stages (step II to V and VI) in time schedule gives better concept of required time to perform the required activities to construct the solar farm. In order to perform two mentioned stages of the project in Iran, 18 months are required, the programming and time schedule could be considered as shown in Table IX [2].

TABLE IX
PROGRAMING TIME SCHEDULE OF PV PLANT INSTALLATION PROJECT

WBS		Tasks	Time days	Duration – Quarter 1	2	3	4	5	6
	1	Site selection	30						
	2	Feasibility study	60						
	3	Authorizations	180						
Development	3.1	Installation license	30						
	3.2	Grid connection plan	90						
	3.3	Environment license	30						
	3.4	PPA	60						
	4	Construction	360						
	4.1	Tendering	30						
	4.2	EPC contract	30						
	4.3	Site preparation	30						
Execution	4.4	Detail Engineering	60						
	4.5	Equipment supply	210						
	4.6	Civil works	120						
	4.7	Erection works	150						
	4.8	Test and Start-up	30						

Preliminary activities to start execution of a solar form project depends on local regulation of the concerned region of the PV plant. For this reason, investors need to determine the required procedure in their considered countries as the priority.

VII. CONCLUSION

1) Main factors of selecting proper location of the PV plant, as well as preliminary estimation of photovoltaic potential of the considered location for installation of the plant are described. This part helps the investor to find out general idea about the capability of the selected region and possibility of returning their investment through this enterprise.
2) Require authorizations, according to Iran regulation, are described. PPA as selected approach to support and convince the investor for installation of PV plant in Iran is introduced. This part provides required confidence and safety condition for the investor about selling of the PV plant yield power which is the fundamental concern of the investor.
3) A scientific approach to determine the required and suitable technology through simulating the concerned photovoltaic plant helps to evaluate the selected technical specifications of PV components and to reach the real performance and annual yield power of the plant. This part helps investor to consider and select suitable components to achieve feasible performance for the plant.
4) A project feasibility study gives information about the selected technology and commercial index of the project. This survey is essential before starting implementation of the whole project. This part describes the financial index of the project to investor and specifies the profitability, the pay back years related to the selected technology and how suitable the selected specifications are as well. Due to the feasibility, to have better financial index condition for investment of the project, some changes to technical specifications of the photovoltaic component is inevitable. This part helps decision makers to be sure about the financial indexes and profitability of the investment
5) Preparing suitable program and time schedule to perform the project activities is vital to finish the project on time

and avoid wasting of time and of course money. This part helps decision makers and investors about following all the required activities according to the priorities and also fluent leading the implementation of the PV plant.

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