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Economic and Environmental Impact Assessment of Micro Grid

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Abstract—**Micro Grid has been considered as a challenge among power utilities as well as communities in many countries around the world. Many studies have been done to date on Micro Grid technology and operations, but fewer studies such as economic and environmental impact assessment still needs to challenge. This paper intends to assess economic and environmental impacts of Micro Grid which forming by renewable energy micro-wind power plant (MWPP), micro-hydro power plant (MHPP) and solar power plant (SPP) and planned to install in a rural area. Yardstick of economic merit such as Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Payback Period (PBP) are mainly presented in this study with environmental impact assessment.**

Index Terms—**Micro Grid, Economic and Environment, Impact Assessment, Rural Area**

I. INTRODUCTION

Micro Grid (MG) is a small power network composed by distributed energy resources (DER) and loads for future electricity power supply. It is a clean, reliable and friendly power network. Form the viewpoint of social impact, Micro Grid can provide cheap power to the local industry and increase the income to the local customers. On the other hand, the renewable energy regard as DER in Micro Grid provides a solution for power supply to the remote rural area is not accessible by the Electric Power Company, this especially useful to the developing countries that are poor in fossil-based resources. In addition, having generators close to demand also cuts down the cost of getting power from a remote national grid to the rural demand, to achieve energy saving [1] [2].

As the development of Micro Grid technologies, including business cases, opportunities, and implementation challenges, the Micro Grid market is heating up quickly, with deployments occurring around the world in a variety of application segments. The industry is moving into the next phase of project development, focusing on how to develop projects on fully commercial terms [3].

As a pre-practical project, a rural area is chosen as a pilot area for installing a Micro Grid. This paper intends to assess the economic and environmental impacts on installing a Micro Grid which consisting of a 32 kW MWPP, a 10 kW MHPP and a 10 kW SPP, in a rural area. Yardstick of economic merit: Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Payback Period (PBP) will be the key for deciding whether to purse project or not in economic impact assessment. Reducing of greenhouse gases particularly in carbon dioxide emission will be the main focus of the environmental impact assessment.

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II. INSTALL A MICRO GRID IN A RURAL AREA

Install a Micro Grid in a rural area can supply the electricity power to the local user with cost saving; can stimulate the local economy, create income and job opportunities to the local people; can attract private investment in the development and widespread use of Micro Grid technology.

A rural area considered in this paper is located in a slope surface with complex geographical shape along the direction from east to west in Yamanashi prefecture. There are 32 households distributed around this area, and rely on agricultural activity for their living. The rural area has no resources for building the large utility for electricity supply. Hence, rely on national grid for electricity supply in this area. In many developing countries, there are many rural areas similar to Yamanashi prefecture, which rely heavily on national grid for electricity transported. Aiming to cut down the electricity loss due to transmission line, and by utilizing the renewable energy to developing a rural area's energy supply, a Micro Grid consisting of a 32 kW micro-wind power plant, a 10 kW micro-hydro power plant and a 10 kW solar power plan planned to install in this rural area for supplying electricity to all residents who are remote from a national grid so far.

The benefits of Micro Grid are proved by comparing the environmental and financial efficiency before and after installation of Micro Grid and will be discussed in the later of this paper. It is also indicated that installation of Micro Grid will boost further the socio-economic development in a rural area for the entire rural community.

III. THE NECESSARY OF MICRO GRID ECONOMIC ASSESSMENT

A Micro Grid consisting of various DER has mentioned above. These economic characteristics are different from each other as well as their dynamics. Some of them are suitable for base load operation and the others may be good for responding to sudden load changes. In addition, several types of them have the capability to supply thermal load besides electricity. By fully utilizing their capabilities, Micro Grid can be operated efficiently and economically. There is an analogy of Best Mix Strategy and Economic Load Dispatch (ELD) for the bulk power system except CHP (Combined heat and power) functions. Moreover, if a contract and provisions allowing, Micro Grid can sell their power to the market through the grid. This is an incentive for investment in Micro Grid [4]. Therefore, the economic consideration of Micro Grid is important issue since it has various distributed energy resources with different characteristics and interaction with the grid should be taken into account for selling/buying electricity from/to the utility. The economics or business case for Micro Grid determines the configuration and operation of Micro Grid. Issues of Micro Grid economics can be roughly divided into three categories as follows [5] [6]:

a) The first concerns the basic economics of optimal investment and operation of technologies available to the Micro Grid. These are problems that, at least at the distribution system scale, have received intense academic scrutiny; as a result, established and reliable tools are available to guide operation and should, with some adaptation to the specifics of Micro Grids, be effective.

b) The second concerns some of the unique aspects of Micro Grids that will require innovation. In general, these are areas in which Micro Grid different significant from distribution systems.

c) The third concerns the relationship of Micro Grids to the distribution system. In many ways these problems resemble familiar ones related to the interface between customers and utilities. For example, they need to provide a real-time price signal to Micro Grid so that optimal use of resources by both Micro Grid and grid can be achieved simultaneously.

IV. ECONOMIC AND ENVIRONMENTAL EMPACT ASSESSMENT OF MICRO GRID

In this section we intend to assess economic and environmental impacts of Micro Grid consisting of micro-wind power plant, micro-hydro power plan and solar power plan. Yardstick of economic merit such as Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Payback Period (PBP) are discussed in detail in this study. The environmental impact of Micro Grid is mainly assessed by the emission reduction of CO2 by using of renewable energy resources in Micro Grid compared with the traditional fossil fuel power plants.

A. Economic Impact Assessment of Micro Grid

According to International Association for Impact Assessment (IAIA), impact assessment is simply defined as the process of identifying the future consequences of a current or proposed action. It evaluates the impact of certain proposal which is very important in the process of decision making. The main purpose of the economic impact assessment is to provide an economic basis of deciding whether to pursue a certain project or not.

Evaluation of the following measurements: net present value (NPV), benefit-cost ratio (BCR) and payback period (PBP) will be the key for deciding whether or not to pursue the project in economic impact assessment. The computation of the total capital cost for 32kW MWPP is given in Table I; Total capital cost of 10kW SPP and 10kW MHPP are presented in Table II and Table III respectively, for economic impact assessment of the Micro Grid. To calculate the yardsticks of economic merit, the electricity price generated by MWPP, MHPP and SPP are based on the electricity price that household pay to electricity company when buying from it originally, and can be assumed as 22JPY/kWh. The useful life of MWPP, MHPP and SPP is 25 years.

1) Net Present Value (NPV)

The Net Present Value (NPV) is the net value of all benefits (B) and costs of the project, discounted back to the beginning of the investment. The benefits will be the income in selling the generated power of the community. The costs constitute the total capital investment (IC) and the accumulated annual operation and maintenance cost (A) which is assumed to be 2% of the total project cost. The NPV is given by the following equation:

$$NPV = NPV(B) - [IC + NPV(A)] \qquad (1)$$

$$\begin{aligned} &Where, \quad NPV(B): NPV\ of\ Benefits \\ &\qquad IC: Initial\ Cost \\ &\qquad NPV(A): NPV\ of\ Annual\ Cost \end{aligned}$$

And,

$$NPV(B) = AES[(1+I)^n - 1]/I(1+I)^n \qquad (2)$$

$$\begin{aligned} &AES: Annual\ Energy\ Sales \\ &Where: \ I\ is\ the\ real\ rate\ of\ discount \end{aligned}$$

$$NPV(A) = A[(1+I)^n - 1]/I(1+I)^n \qquad (3)$$

Where, B shows all benefits (annual energy sales), A, shows annual operation and maintenance cost (Annual cost) and I shows the real rate discount. For 10kW MHPP to install in the Micro Grid, the NPV will be calculated as the following:

$$NPV = 27{,}161{,}849.97 - (5{,}494{,}973 + 1{,}548{,}916.9) = 2.01(Million\ \ yen)$$

Since *NPV* is greater than zero, the supposed project is economically acceptable bringing profit to the investor.

2) Benefit-Cost Ratio (BCR)

The Benefit Cost Ratio (BCR) is the ratio of the net present value of the total benefits to the net present value of all the cost plus the investment cost. BCR is calculated by the following equation:

$$BCR = NPV(B)/[IC + NPV(A)] \qquad (4)$$

Therefore, for the 10kW MHPP, the BCR can be calculated by equation (4) as shown below:

$$BCR = NPV(B)/[IC + NPV(A)]$$
$$= 27,161,849.97/(5,494,973 + 1,548,916.9)$$
$$= 3.86$$

Since BCR is greater than 1, that the supposed project is acceptable.

3) Payback Period (PBP)

The Payback Period (PBP) is the year (n) in which the net present value of all benefits will be equal to the net present value of all the costs plus capital investment. At the PBP,

$$NPV(B) = [IC + NPV(A)]$$
Solving for n yields ,
$$n = -\ln[1 - (I \times IC)/(B - A)]/\ln(1 + I) \qquad (5)$$

Therefore, for the above 10kW MHPP, the payback period can be calculated as below:

$$n = -\ln[1 - (0.05 \times 5,494,973)/$$
$$(1,927,200 - 109,899,46)]/\ln(1 + 0.05)$$
$$= 3.36\,(year)$$

The calculation result shows 10 kW MHPP operating in Micro Grid will start to gain the profit after nearly 3.4 years. Under the same principle, the economic assessment on 32 kW MWPP and 10 kW SPP are calculated given in Table IV.

It is known that the economic assessment of the installation is in relation to the local efficiency. That is, the higher efficiency it is, the investment will be sooner be recovered. From the result of simulation, indicated that the payback for MHPP is 3.4 years, MWPP is 4.6 years and SPP is 13 years. This proved the system is much more efficient than before introduce the Micro Grid to this rural area. Because only 3.4 years for MHPP, 4.6 years for MWPP and 13 years for SPP are enough to recover the high cost of the installation.

TABLE I
TOTAL CAPITAL COST FOR 32 KW MWPP

Description	Cost(yen)
Civil Works (11% of project investment)	880,000
32 kW Wind Turbine-Generator and Accessories (180,000 yen /kW)	5,520,000
Electrical Infrastructure (Transmission Line, etc.) (9% of Investment)	720,000
Power Conditioning (7% of project investment)	560,000
Installation and Other Miscellaneous Charges (4% of Investment)	320,000
Total Capital Cost of Project	8,00 0,000

* 1USD=120JPY

TABLE II
TOTAL CAPITAL COST FOR 10 KW SPP

Description	Cost(yen)
Total Capital Cost of Project	6,666,000
Capacity Factor	0.4
Rate of Discount	0.05
Operation and Maintenance: 1% of Capital Cost	66,660

* 1USD=120JPY

TABLE III
TOTAL CAPITAL COST FOR 10 KW MHPP

Description	Cost (yen)
Civil Works	2,500,000
Penstock (20m pipe, 5050 yen /m)	115,000
7 units -1.4 kW Turbine-Generator and Accessories (121,200 yen /unit)	960,000
Transmission Line	172,500
Substation (step-up and step-down)	287,500
15% of electromechanical equipment	231,150
20% of civil works	500,000
20% of Direct Cost and Contingencies	954,430
Sub-Total	4,995,430
Interest(10% of Sub-Total)	499,543
Total Capital Cost of Project	5,494,973

* 1USD=120JPY

TABLE IV
ECONOMIC ASSESSMEN OF MICRO GRID

THE ITEM	NPV(JPY)	BCR	PBP(YEAR)
MHPP(10KW)	20117960.1	3.9	3.4
MWPP(32KW)	20166240.8	3.0	4.6
SPP(10KW)	3259237.64	1.4	13

B. Environmental Impact Assessment of Micro Grid

The impact of renewable energy resources in Micro Grid is not only in economic term but environmental as well. That is, the amount of gaseous pollutants released into the atmosphere for production of power is significantly reduced when using renewable energy resources instead of traditional plants. It is to say that, it is necessary to change the pattern of energy consumption from heavily depending on fossil fuels such as oil, coals etc. to introduce renewable energy resources for future electricity power generation. This is particularly important problem since electricity power generation emissions contribute a significant proportional of overall emissions that cause the global warming and the greenhouse effect.

In this study, the total monthly supply of MHPP is 7,440kWh and the monthly power demand is 23,379.46kWh. It is interesting to determine the amount of carbon dioxide emission and it will be reduced per month, if to install a Micro Grid taps some its electricity from MHPP. According to the local Electric Power Company, The CO2 emission intensity of grid power supply is 0.381Kg/kWh. For micro-hydro power plants, the CO2 emission intensity is 0.011Kg/kWh, for micro-wind power plants and solar power plants, they are 0.0295Kg/kWh and 0.072kg/kWh. The emission intensity figures are based on life cycle analysis which incorporates the emissions from construction, operation, dismantling and disposal. Fig.1 shows a monthly amount of CO2 emission from the Micro Grid compared with the traditional plants. The total and avoided CO2 emission by introducing of MHPP, MWPP and SPP in Micro Grid are calculated given in Table V.

TABLE V
AVERAGE MONTHLY AMOUNT OF CO_2 EMISSIONS REDUCED BY INTRODUCING OF MICEO GRID

CO2 Emissions(tons/month)	MHPP	MWPP	SPP
From main grid		9.2	
Avoided from each resource	2.83	1.75	4.91
Reduced by using of each resource	30.8%	19%	53.4%
From the Micro Grid		1.2	

From the result, it is show that the total amount of CO2 emission will be reduced 2.83tons, 1.75tons and 4.91tons for

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an average one month when the load takes most of its energy supply from MHPP, MWPP and SPP. It can be say that a total of 8tons CO2 emissions can be avoided by installing Micro Grid in an average one month in this rural area. This is indeed a worth noting environmental impact of installing MHPP, MWPP and SPP of Micro Grid to this target rural area.

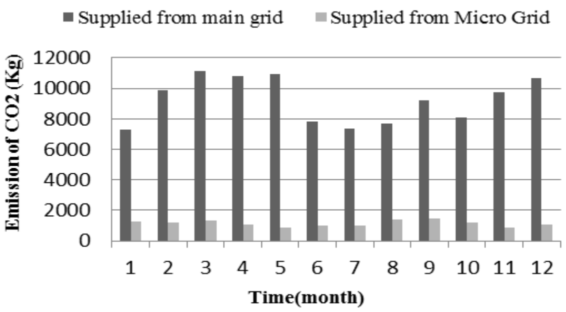

Fig.1. CO2 emission from MG compared with traditional plants

V. COST OF ENERGY FROM MICRO GRID HYBRID SYSTEM

Long power transmission lines have high power loss in a certain degree. This research show that by installing Micro Grid in a rural area to supply a local energy demand will be an effective way to developing the renewable energy resources, to cutting down the cost of getting electricity from the national grid and can avoid the long transmission power loss. In this study, it is also show that installing of Micro Gird with hybrid MHPP, MWPP and SPP will be economically and benefits for the cost of energy saving by supplying electricity to the target rural area. A certain amount of load demand will get the electricity supply from Micro Grid. In this case, the supply is not only service the demand but also they are used to save electricity in storage battery or selling back to the electricity power company. Supposed that, the surplus electricity selling to the electricity power company is usually considered as 8JPY for per kWh and buying insufficient electricity from the electricity power company is usually considered as 21JPY for per kWh. By comparing with the conventional electricity power system and the Micro Grid hybrid system for the consideration of the cost of energy, we obtained the following result shown in Fig.2.

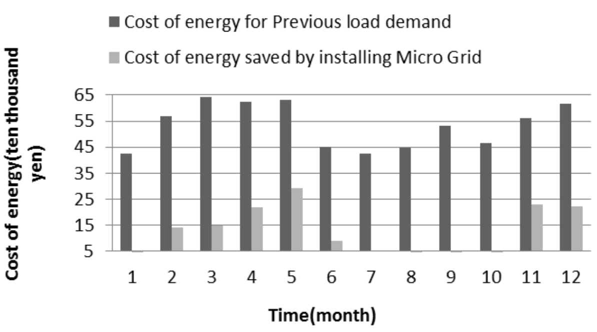

Fig.2. Comparing the cost of energy before & after installing MG in a rural area

VI. CONCLUSION

a) In this study, economic and environmental impact assessment of Micro Grid is presented. The result of economic impact assessment shows that the net present value became greater than zero, the benefit-cost ratio are respectively 3.9, 3.0 and 1.4 for MHPP, MWPP and SPP. Under the condition, Micro Grid system may start to gain the profits after the payback period of 3.4 years for MHPP, 4.6 years for MWPP and 13 years for SPP. These numbers show that it's economic feasible for installing Micro Grid in this rural area.

b) Environmental impact assessment of Micro Grid is proved by the result of total amount of CO2 emission that will be reduced 2.83tons, 1.75tons and 4.91tons for average one month from MHPP, MWPP and SPP respectively. About 9tons of CO2 emissions are reduced for one year by installation of Micro Grid in a target rural area. Besides, the cost of energy is discussed in this study for the benefits of Micro Grid.

c) This study indicates that the introduction of Micro Grid in a remote rural area may improve the local economy and also positive impact on environment. The founding of the preserve research is believed to be useful for many countries who, are going to take advantage of the Micro Grid to supply electricity independently according to the necessary demand for their needs in future.

d) Finally, Micro Grid will not only bring the economic but also environmental benefits for a rural area and increasing the development of the social economic. For example, workforce of the local community will be increase, and awareness of environment protection of local public will also be increasing etc.

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