Key Issue:
1-Biological Diversity
10- Landscape and Cultural Heritage

Climate Zone:
Cf: Temperate Humid Climate

Subjects:
- Slope Afforestation and Revegetation in Harmony with Surrounding Environment

Effects:
- Early restoration of landscape and ecosystem in developed areas

Project Name: Shin- Hannou Substation
Country: Saitama Prefecture, Japan (Asia)

Implementing Party & Period
- Project: Tokyo Electric Power Co., Inc. (TEPCO)
1994 (Commencement of construction) -
- Good Practice: Tokyo Electric Power Co., Inc. (TEPCO)
1994 -

Key Words:
Biodiversity, Revegetation Methods, People-friendly Forests

Abstract:
In the construction work of the Shin-Hannou Substation, the idea of biotope was incorporated in the design stage and a variety of environmental measures were taken with the aim at its coexistence with nature. Particular attention was paid to the restoration of ecosystem at low costs through the application of the power of nature. For example, for the afforestation of slopes and the development of forests, plants were raised from seeds to use their inherent power to vegetate. Besides, watersides spaces in which wild animals and plants were habitable were created. The methods and the ideas adopted in this project are applicable not just to the construction work of substations but also extensively to large-scale projects including hydropower development.

1. Outline of the Project

The Shin-Hannou Substation construction work is to build a 500 kV substation in Saitama Prefecture, in the site shown in Fig.-1, to meet the demand for electricity in the southwest area of the prefecture and the northwest area of Tokyo adjoining it and to strength the bulk power system. Specifications of the substation are shown in Table-1.

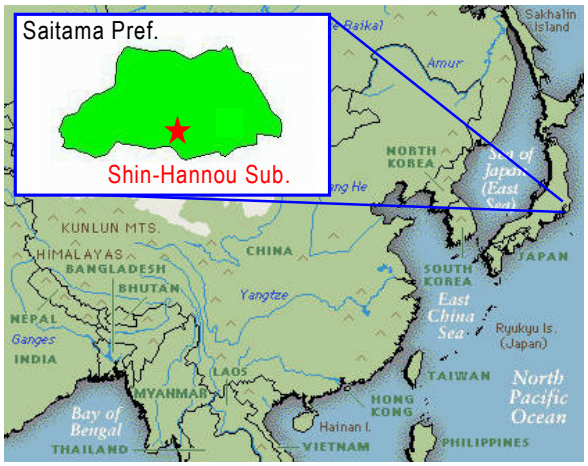


Fig.-1 Map of the location

Table-1 Specifications of the Shin-Hannou Substation

- Outline of facilities

Facilities		This Stage	Final Stage
Main Transformer	500/275kV, 1,500MVA (with a built-in LRT)	2 banks	4 banks
Bus	500kV	Unit bus	Double bus with 4 bus-ties
	275kV	Single bus with 1 bus-tie	- ditto -
Transmission line terminal	500kV (overhead)	2 circuits	6 circuits
	275kV (overhead)	2 circuits	6 circuits
Rotary Condenser	Advanced phase Capacity 200MVar Lagging phase capacity 70MVar	1 unit	1 unit

- Total Area 17.8 ha
- Access Road Length: approx. 2.1 km, Width: 6 m, Max. Gradient: 12 %
- Site Area 4.8 ha
- Elevation 360 m above sea level

2. Features of the Project Area

The construction site of the Shin-Hannou Substation is within the Prefectural Okumusashi Natural Park located in a place between hills in Hannou City, which publicizes itself as a “town of green and limpid streams.” The site is in an urbanization control area. The areas around the site are abundant with rivers and natural forests but it takes only an hour or so by train from a downtown of Tokyo. As it is located so conveniently, people make a company of nature on holidays by fishing or bathing in a river and mountain walking. On the other hand, the construction of new towns and estate development for golf courses are under way now. Such a situation aroused environmental consciousness of both the administration and the inhabitants and as much endeavor as possible to maintain harmony with the environment of surrounding areas was demanded in the construction of the substation.

3. Major Impacts

Starting an environment impact assessment in 1994, the Tokyo Electric Power Co., Inc. prepared a report on its investigations of environment impact upon completion of the construction work in April 1994. Such investigations are still continuing.

The local autonomous body (Saitama-ken) stipulated "the Ordinance for Protecting Green in Saitama, Our Homeland," setting a goal of increasing afforested areas in it to 6,600 ha by 2005. On the basis of the ordinance, developers in the prefecture are required to sign "the Green Agreement" and to maintain a certain afforestation rate (2/10 minimum of the area of a construction site (or, in the case of extension work, of the area of the extended space)). For the construction of this substation, the development was attached with conditions that an afforestation rate of 20% should be secured and that planted trees should be at least 180 cm in height on an average at the completion of the work.

Accordingly, in this construction work, to erase traces of construction work as much as possible in the areas to be developed and to restore the ecosystem, which had been reared by the forests of the Okumusashi region, were major environmental problems.

4. Mitigation Measures

In the environmental planning in this project, emphasis was placed on the use of an afforestation method that would allow the abovementioned problems to be solved, and on the selection of plants that would work as the most effective means for early restoration of the ecosystem. Special attention was paid to the following:

1) Designing slope afforestation works that could minimize concrete structure;
2) Designing a regulating reservoir and a waterway in consideration of the ecosystem; and
3) Early restoration of a landscape and an ecosystem in harmony with the environment of surrounding areas.

Concrete measures as shown below were taken to attain the objects 1) to 3). For examining and taking these measures, local administrative offices' and inhabitants' understanding was sought and their acknowledgement was obtained.

1) Slope afforestation works was designed so as to minimize concrete structures.
   a) Nature-like cut retaining walls by the geofiber method
      (Using the geofiber method for cut portions achieved the planned afforestation without making concrete block retaining walls for slope protection.)
   b) Nature-like retaining walls of embankment by the geogrid reinforced earth method
      (Using the geogrid reinforced earth method served to do away with concrete retaining walls and at the same time to reduce the area of development in achieving the planned slope afforestation.)
   c) Such manurial plants as bush clover and maackia were mainly selected in designing slope afforestation.
      (The shotcrete works with the base concrete mainly containing seeds of manurial plants served to do away with slope landslide prevention works and to achieve the objective of slope protection by afforestation.)
2) A regulating reservoir and a waterway were designed in consideration of the ecosystem.
   (So that a regulating reservoir and a waterway could provide water amenity spaces for small animals and aquatic life, concrete structures were reduced to a minimum necessity

and a nature-like waterway was created by arranging native rocks.)

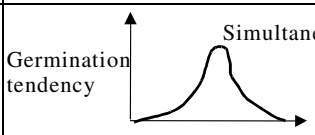
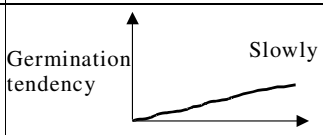
3) Early restoration of a landscape and an ecosystem in harmony with the environment of surrounding areas
(Directly seeding native species of deciduous broadleaf trees and evergreens improved ground conservation and materialized early revegetation.)

Of the above measures, particularly unique ones are detailed in the following.

4.1 Design of slope afforestation mainly with such manurial plants as bush clover and maackia

In the process of building a substation, large slopes are produced as a result of road and land development works. When such slopes and bare land are produced as development work progresses, prompt restoration to their original states is required not only from the viewpoint of appearance or landscaping.

Table-2 Germination and growth characteristics of herbaceous plants and woody plants

Item \ Division		Introduced Herbaceous Plants	Woody Plants
Germination characteristics & conditions	Germination rate	Very good (80-90%)	Not good (20-60%)
	Germination tendency		
	Germination bed	Thick bed not necessary (surface seeding) Should be free from erosion for 2-3 weeks	Thick bed necessary (Seeds to be buried in the ground) Should be free from erosion for long time (A few month-next year)
	Climate	Temperate and humid (for short period of time)	Temperate and humid (for long time)
Growth characteristics & conditions	Geology	Soil height: Sandy soil <25mm Cohesive soil <23mm	Soil height: Sandy soil <25mm Cohesive soil <25mm
	Gradient	45° or gentler	Gentle slope of 60°
	Fertilizer Requirement	Large	Small (manurial trees)
	Climate	To grow in temperate and humid environment	To grow in temperate and humid environment
	Speed of growth	Fast	Slow
	Height of grass or tree	Low	High
	Depth of root	Shallow	Deep (Grass roots elongate relatively deep.)
	State of growth	To grow in crowds easily (To wither all together when they grow thick.)	To be scattered gradually (In case of large number of varied species, pressure exerts.)

For such slopes and blighted areas, in association with construction work, covering with exotic herbage or prevention works using herbage in combination with grating crib works have been adopted so far in most cases. As shown in Table-2, whereas exotic herbs are excellent in germination and quickly grow in gregariously, they are known to have control and maintenance problems frequently degenerate in two or three years after the completion of work because of their high requirements for fertilizer.

On the other hand, woody plants (manurial plants) extend their roots deep into the ground once they start growing and form a root system layer although their rate of initial germination is low and so they can increase the stability of slopes. The problem in using woody plants is how to prevent erosion during the period preceding their germination.

Such being the case, "the higher-mode aggregated shotcrete works" was chosen for the project. This is the method to pneumatically convey higher-mode aggregated soil having features similar to forest soil onto slopes by means of a pump. (The aggregated soil is highly air- and water-permeable, porous soil in an advanced state of decomposition.) This is an excellent method that not only creates highly nutritive soil layers but also prevents erosion of the surface layer of a slope.

One of the most important matters in restoring a slope on which violence is done by development is to set "a target community" by looking far into the future. In the present case, a community having the following functions was targeted. Further, so as to do away with as many concrete structures as possible, particular attention was paid to protection and afforestation of cut slopes and slopes of embankment produced as a result of clearing a hilly landform.

1) The function to adapt to infertile land and dry land, be capable of germinating and growing on a steep slope and have soil improving ability;
2) The function to bind soil tightly, extend the root system deep into a slope and retain weathered soil layers; and
3) The function to grow quickly, integrate in trees and shrubs in surrounding areas and efface traces of development.

   As a result of searching plants that could fulfill the above functions and carrying out field tests, a blend of bush clovers, maackias, indigo plants and sericeas was found to attain the best balance (Table-3). These manurial plants function to fix symbiotic free nitrogen and improve soil.

Table-3 Blend of seeds

	Plant name	Rate of germination	Effective number of grains/g	Anticipated number of plants/ m^2	Seeding quantity (g/m^3)		
					Spray thickness: 2cm (standard thickness)	Spray thickness: 3cm	Spray thickness: 3cm-5cm
Low trees	Bush clover	50%	68	1,000	29.42	44.13	29.42
	Maackia	80%	38	150	4.93	7.40	4.93
	Indigo plant	50%	120	150	2.50	3.75	2.50
Native species	Sericea	50%	494	500	2.02	3.03	2.02

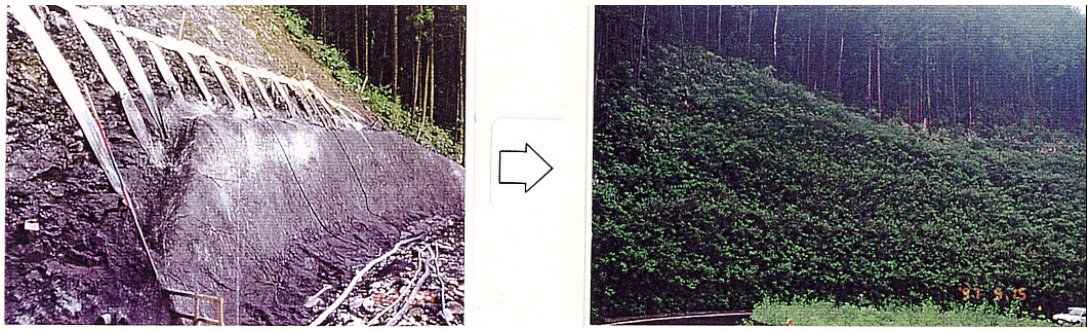


Fig.-2 Slope afforestation using mainly manurial trees
(Photo shows the geofiber method + afforestation)

The total area of afforestatin using woody plants is 11.8 ha.

4.2 Design of regulating reservoir and waterway in consideration of the ecosystem

1) Nature-like waterway made in upper stream of regulating reservoir

In consideration of the local topography, geology and stream regime, the waterway connected to the regulating reservoir with the capacity of 18,000 m^3 was built as a nature-like biotope waterway defined by randomly placed native without using concrete. As a result, nature has been restored and water amenity spaces have been created (Fig.-3). In this process, a great deal of effort went to the creation of as many porous spaces as possible for providing small animals with habitats and the formation of meanders for the waterway.

Fig.-3 Nature-like waterway

2) Design of waterway in consideration of living things

For the waterway, an animal-friendly configuration was adopted; in portions of the waterway of which three sides were made of concrete since a nature-like form could not be retained due to limitations in space of the site, the bottom of the waterway was covered with earth, sand and gravels and sloped steps were provided for animals' access to the water.

4.3 Design of early revegetation by direct seeding

To secure the afforestation rate for this substation, limitation in the area of developed land made it inevitable to plant trees on the slopes of embankment. Nevertheless, the slopes of embankment of the substation required not only the fulfillment of the afforestation rate by tree planting in harmony with the environment of surrounding areas but also the quality that could concurrently play the role of slope protection works from the standpoint of disaster prevention. Therefore, an afforestation design was made on the basis of a survey of vegetation in search of a method for restoring nature in revegetated forests, for which potential natural vegetation of surrounding areas was taken into account.

Table-4 Potential natural vegetation based on survey

Potential natural vegetation	Form of colony	Potential location	Corresponding existing vegetation
Fir/Japanese star anise community	Mixed coniferous and broad-leaved forest in which fir and oak trees grow mixedly.	From ridge to middle of slope where dry, brown forest soil and slightly dry, brown forest soil are distributed	- Fir/Quercus glauca community - Quercus/Japanese chestnut tree community - Aralia elata/ Rubus hirsutus community
Zelkova tree/ Japanese maple community	Broad-leaved forest in which zelkova trees and oak trees grow mixedly; ever-greens have priority in forest	Bottom of ravine and lower portion of slope where dry, brown forest soil and appropriately wet brown forest soil are distributed.	- Japanese cedar/ hinoki cypress plantation - Disporum sessile group. - Acer plamatum/ Rubus hirsutus community and others

For the execution method of affrestation with these native plant species taken into consideration, direct sowing by means of seeding works (from seeds to germination and growth) was chosen to balance the above-the-ground portion (trunk, branches and leaves) and the subterranean portion of the plant. As the method of construction, the higher-mode aggregated shotcrete method was employed as mentioned earlier.
The area of revegetation by direct seeding is 3.2 ha.

5. Results of the Mitigation Measures

To assess the impact of the construction work on surrounding environment, environmental impact survey s have been continuously carried out since 1994. Although it was feared that the intended rate of afforestation could be reached at the completion of the substation by revegetation through direct seeding instead of the conventional method of tree planting, deciduous trees grew satisfactorily as shown in Fig.-4 and 5 and it was assured that the target (an average height of trees at the time of completion: 180 cm) stipulated by “the Green Agreement” with Saitama-ken could be achieved (Fig.-6).

Fig.-4 Present state of afforested area (1)
(the photo on the right shows a Quercus)

Fig.-5 Present state of afforested area (2)

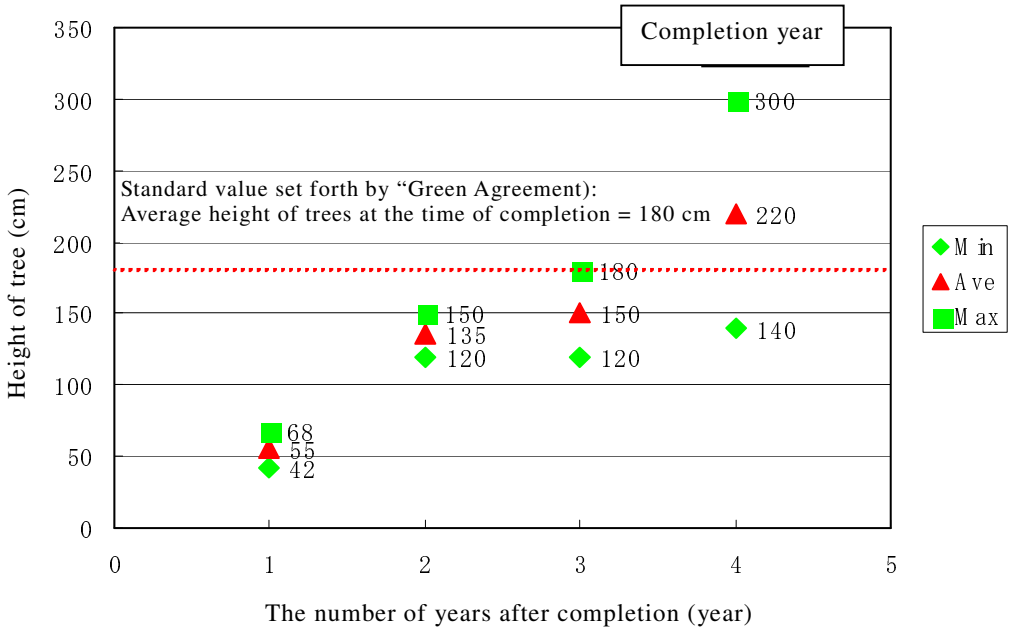


Fig.-6 Changes in the height of deciduous tree

6. Reasons for Success

Prior to the start of the construction work, specialists including members of the Japanese Society of Greening Engineering were invited to form the "Early Revegetation Study Team" and the construction work was carried out while examining proposed measures for environment protection and their effect. This is believed to be a major reason for a generally satisfactory result of the environmental protection measures.

7. Outside Comments

1) Nikkei Construction, November 1997
   Rated the project high as a good example of "preventing nature from being lost by development."
2) Magazine "Sun," December 1996
   Taking up "The Shin-Hannou Substation" as an attempt for symbiosis with nature, featured "the biotope technique" and "slope protection by making use of supporting force of roots of plants."

8. Further Information

8.1 References

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4) Miyawaki, Akira (National University of Yokohama): “Potential natural vegetation of the Metropolitan area,” 1976

8.2 Inquiries

Construction Department
Tokyo Electric Power Co., Inc. (TEPCO)
Tel: +81-3-4216-8111
Fax: +81-3-4216-4269
e-mail: http://www.tepco.co.jp