

National PV Centre for Sustainable Development of PV Technology in Developing Countries

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Abstract— Photovoltaic (PV) systems are the most reliable technology for rural development. The PV has many contributions to make in developing countries, and its applications impinge on the work of many different Ministries. PV technologies need successful implementation to take activities into the target. There are a number of factors that can promote PV technologies and PV development. The central government has to establish a centre of excellence at the national level and give the policies to the centre for promoting the PV technology and development across the country. A role of the National Photovoltaic Centre is one of the most important implementations for sustainable development of PV technologies. The purpose of this paper is to discuss and focuses on the role of the National Photovoltaic Centre that is possible to conduct. This can be done by formulating integrated energy policies and programme as well as providing education, information service, collaboration, research and development, implementing training and demonstration. It is recommended that the PV centre need to have some important activities to conduct for PV development, such as research and development, collaboration and training. This is essential to provide important opportunities and to acquire new technological knowledge and skills.

Keywords—Photovoltaic Centre, Training.

1. INTRODUCTION

PV systems now provide power for hundreds of thousands of installations worldwide, and have been used in numerous applications, such as water pumping, telecommunication system, battery charging, vaccine refrigeration and so on. A photovoltaic project will become a successful project if it has a good implementation of PV both before and after the PV system is installed. The impediments to its widespread use are now largely not associated with the technology, but with its implementation. The main problem is in the capability of developing countries to receive the technology transfer and makes appropriate use of the technology. The widespread public dissemination requires a range of institutional structures and technical skills on which it can draw. The availability of these

structures and skills is the measure of the capability of a country to receive the transfer of PV technology and use it for the benefit of society. In general, good organisation and training are necessary for the development of endogenous capabilities in PV. It is important that a centre of technical expertise or a National Photovoltaic Centre need to be established in each country that can act as the conduit between policy formulation and the PV users. In addition, the centre needs to be aware of the developments in photovoltaics around the world and able to select appropriate technical developments and products for application in their own country. One of the major roles that the National Photovoltaic Centre must conduct is research and development including training course. Furthermore, collaboration with some PV institutions both at international and national level, and services as a forum & information source is activity of the National Photovoltaic Centre as well.

2. NATIONAL PHOTOVOLTAIC CENTRE NEEDS

There are a number of ways that can promote PV technologies or PV applications within a country, for example, PV demonstration programme and technology transfer. The type of PV programmes being implemented also varies considerably. Some PV systems may be installed as demonstrations under a bilateral aid programme. The large PV programmes are incorporated into the economic activity of the country. These programmes conduct either through commercial activity or through government inspired schemes of rural electrification. The technology transfer can directly from a PV company to a village in a developing country or through intermediaries. Since there are a number of PV systems have been installed worldwide, and the dissemination of photovoltaics is necessary to ensure that the PV programme will be successful. The National PV Centre can play a major role in facilitating the dissemination of PV through the provision of information and training. In order to set and maintain standards for PV modules and components, the government needs a centre of technical expertise. This centre can also assist in the establishment of local industries for the manufacture of PV systems, components and eventually perhaps of modules. The best ways it must be established at the national level by the host government which can in-cooperate all of

institutions that concern with PV technology or/and PV programme. They are international PV companies, engineering firms, international consultancy and others. Typically, a national PV centre is composed of the major activities (or divisions), namely research and development, collaborations, forum & information source, PV engineering consultancy and training. Each division or activity has a responsibility for helping to make PV become the power of choice, and helping to promote PV dissemination within the country. The main aims of the National Photovoltaic Centre (NPVC) are to perform national (or international) research and development, to promote partnering and growth opportunities, and to service as a forum and information source including offer a training course. It can be said

that all PV programme start at the stage of PV demonstration, in order to gain the confidence of potential users, and the NPVC will support that PV programmes. At least initially, it would be the major receiver of high level training and the major provider of intermediate and low level training & indigenous personnel. However, the primary need of the NPVC is for expertise in the engineering of PV systems including their cost effectiveness for the various applications in local conditions. It is most effectively if the training activity is placed to be an important part of the National Photovoltaic Centre 's organisational chart. A conceptually main division of the NPVC based on the activities that the centre should conduct, it is shown in Figure 1.

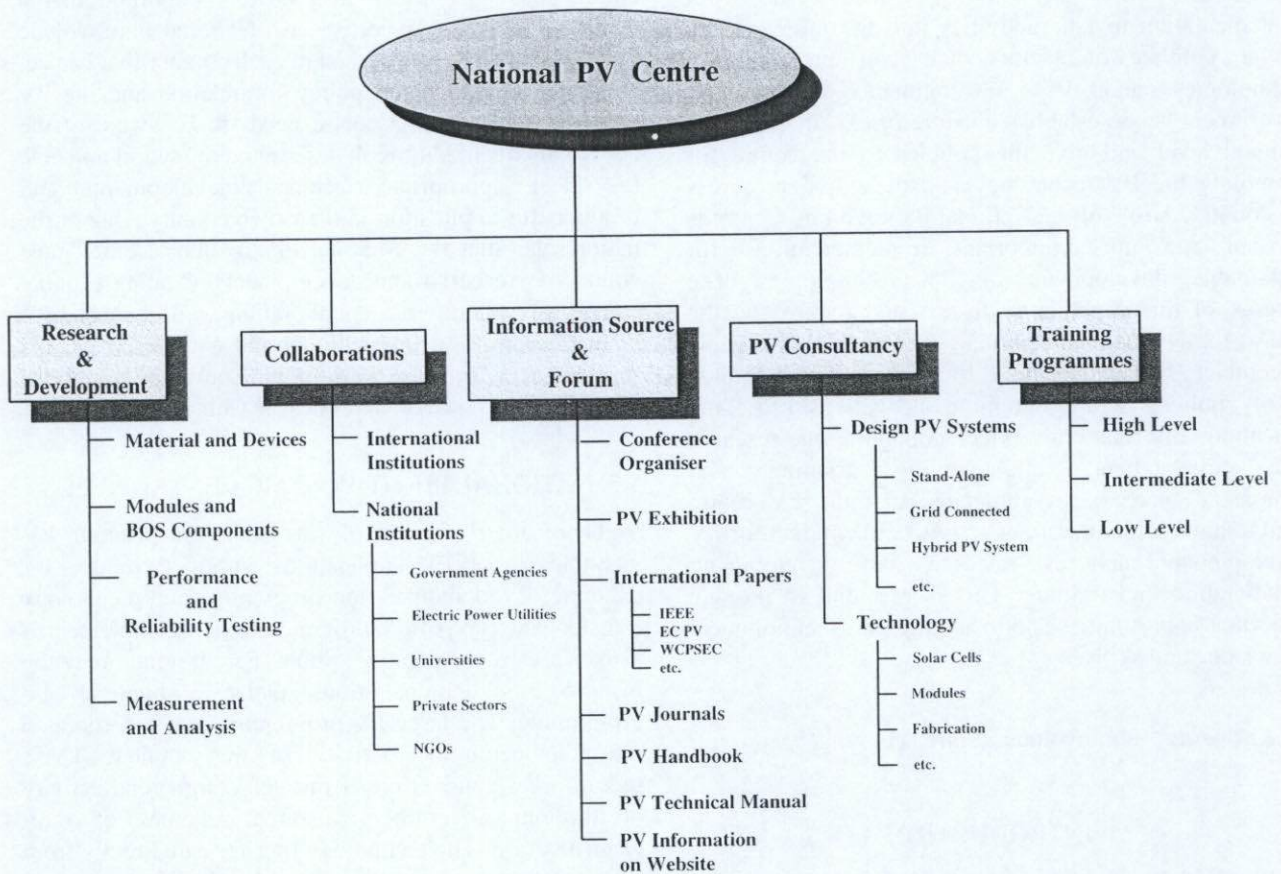


Figure 1. A conceptually main activity/division of the National PV Centre

As can be seen from the figure 1 that there are five possible activities or divisions, each division has a responsibility in different ways. However, the number of divisions in the NPVC in each country may differ because the environmental and social are different. There are a number of factors that affect to set up the NPVC, such as economic growth, social impact, local condition and so on. In the case of the PV centre in developing countries cannot set up all of the divisions that are shown in the figure 1. It is recommended that the PV centre should have these activities, namely research and

development, collaboration and training. Since the centre needs research and development laboratories and core competencies create, develop to deploy PV and related technologies including training activities to create the engineer, technician and skilled staff. Furthermore, collaborations with some PV institutions that concern PV technologies at international and national level to look for ways to expand PV applications, to help the nation's PV industry and end users, and to expand the market for PV product.

3. ROLE OF THE NATIONAL PHOTOVOLTAIC CENTRE

The government needs a PV centre in order to set and maintain standards for PV modules and components. The centre needs to be aware of the developments in PV around the world. Institution has to be established at the national level and be given the mandate to promote the technology. The role of the NPVC is one of the important implementations to promote the dissemination of PV technologies. As previously mentioned, the PV centre should consist of the main divisions or activities, namely research and development, collaborations, forum and information source, and PV consultancy. The responsibility or duty of each division will be discussed as follows:

3.1 Research and Development

The aim of this activity is to research continuously on a variety of familiar and novel PV materials including testing and demonstration. The technology must be improved and electricity from photovoltaics must become more cost-competitive. Development more efficient solar cells and finding ways to improve manufacturing processes and module design is one of the most activities in this area. In general, most of the regular budgets will be distributed for research and development, because it needs a lot more budgets to spend a various resource, such as expert researcher team, high standard equipment, computational tools and so on. Furthermore, most companies cannot afford large research facilities of their own. Since the national PV programme usually conducts long time, high risk, development and testing of PV components and systems in partnership with the PV industry and high-payoff research. The facilities of the NPVC can provide or make this possible. Typically, research and development generate new approaches by turning researchers' ideas into laboratory experiments and prototype devices. In this area the NPVC should be able to conduct in material and device development, module and balance of system (BOS) components' development. In addition, they include market development, performance and reliability testing, measurement and analysis. They are possible activities as follows:

3.1.1 Material and device development

In this area, scientists and expert researchers conduct basic and applied research on promising new material, processes, devices and production techniques. The NPVC must provide laboratories that can research capabilities span the growth and application of a wide range of innovative semiconductor material and study the prototype from the new materials. Scientists or researches can use state-of-the-art equipment and techniques to design and fabricate of PV devices, and can move ideas from the drawing board to the laboratory

bench-scale and prototype development. Key to the success of the programme element is the evaluation of new concepts and materials through careful measurements and modeling. The main skill and ability include experimentation with photo-electrochemical process, solid state spectroscopic analysis, and the application of advanced theoretical and computational tools for predicting the behaviour of new PV materials. Moreover, to analyse minute surface characteristics of PV materials that affect electrical performance is necessary for researching in this area.

3.1.2 Module and BOS components development

Although the development of PV cells to increase the efficiency has been done for many years, the technologies need to achieve costs/unit area of solar cells as low as possible and offer a 30 year lifetime. The efficiency of commercial has been increasing year on year, gradually through process optimisation, and with occasional step changes as techniques develop in the research laboratories enter commercial production. This laboratory has to provide facilities for the development of PV cells including fabricating and evaluating of thin film technologies [amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium diselenide (CIS)], crystalline silicon cells and modules. Furthermore, the development of concentrator PV cells and PV arrays should be conducted including developing and testing BOS components, such as charge controller, inverter, batteries, wiring, control system and so on. Today, BOS components represent half the cost of a PV system, they are responsible for 99% of system repair problems. To increase the efficiency of BOS components of PV systems is the challenge of the technology development portion of this area. The cost-effectiveness and reliability with which a PV system can provide a service depend as much on the BOS components as on the PV modules themselves, and their future developments are essential factors in the future prospects for PV.

3.1.3 Performance and reliability testing

The laboratories must provide testing PV devices and systems to serve several purposes. For example, (a) increasing long time performance of PV modules by performing accelerated aging tests, (b) calibration of reference devices for irradiance monitoring and determination of power rating, (c) development of specialist test equipment and methods. Moreover, prototype PV cells, modules and systems can be tested to verify performance and improve reliability. The specialised scientists, engineers and researchers can use indoor laboratories, outdoor test beds and field trials to evaluate PV technologies under simulation and actual outdoor conditions. In the case of outdoor test facility should include outdoor accelerated-weathering tracking system, flexible system characterisation test bed, high

voltage stress test bed, and expanded performance including energy rating test bed. The expert staffs at the PV centre have to be able to advise on many particular features of modules. This advice is available both at the design stage and after prototype has been tested. It can be given on a number of topics that regularly cause manufacturing or operational problems.

3.1.4 Measurement and analysis

This laboratory should provide facilities for expert staff who will provide analytical support that covers the test and measurement range from atom through PV arrays. Since the state-of-the-art equipment and facilities, the laboratories embody cell and module's performance including analytical microscopy, electro-optical characterisation, surface and interface analysis of materials are included for researching. Furthermore, the development of special measurement techniques and instrument, computers modeling of system and component performance are included as well. The facility of laboratory should offer more techniques to measure electrical and optical properties of materials and devices. To estimate solar radiation by using state-of-the-art measurement system is traceable to world standards. Models, maps and electronic data must be provided to estimate the distribution of solar radiation for specific locations.

3.2 Collaborations

One of the main activities of the NPVC is to collaborate with both international and national institutions that concern in PV technologies. In fact, there are a number of international PV organisations, such as in USA, UK, and Japan that the PV centres in developing countries can work with them, and can work with local industries, universities and private sector. In addition, the PV centre can also assist in the establishment of local industries for the manufacture of PV systems, component and eventually perhaps of PV modules.

3.2.1 International institutions/collaborations

PV technologies should be used on a global basis to solve global problems and there should be global collaboration. PV products must not only work well, they must also meet internationally recognised standard performance and safety criteria. To be successful in global markets, the NPVC must collaborate with other organisations/ agencies to ensure high quality and reliability. Specialists work with international organisations to establish a uniform standards and test methods. Rigorous testing ensures that the electrical, mechanical, and safety aspects of PV systems are sound. Generally, there are no guidelines in developing countries, such as how to produce a reliable product,

how to install them or how to repair them in the systems. Nevertheless, lack of approved testing laboratories makes product testing different for manufactures. In this case, one effort to specify the performance and safety of PV systems is the PV Global Approval Program that was initiated to provide this resource. To develop both domestic and international standards, codes and certification programs for PV products are one of the activities of the PV centre. The collaboration between the NPVC and international PV organisation leads to the successful research and development.

3.2.2 National institutions/collaborations

Some organisations from the government agencies, private sectors, and universities can work with the NPVC. Namely, specialised scientists, engineers and researches in the national labs can work with the industry and university colleagues through the thin film PV partnership project to better understand and improve PV thin films, such as cadmium telluride, copper indium diselenide and amorphous silicon. Knowledge of new technology from PV centre's laboratory or university's laboratory can be discussed by the researchers from them. Universities play a key supporting role in almost every phase of technology development from basic research to developing new manufacturing processes to deploying and testing prototype. The NPVC can draw on the core expertise of other requires to guide operations and coordinate support from other national PV resources. These resources include private sector's laboratory, many universities and industry resource partners across the country. By facilitating greater communication and cooperation between researcher at all of these facilities, the NPVC should have the effective capabilities of each, and links them, so that they function as a unity. The centre can also coordinate activities in the PV community with other local PV projects that is conducted by the government agencies or private sector, and help people come together to work with the PV centre. Furthermore, it must look for the ways to expand PV applications to help PV activities within the country.

3.3 Forum and Information source

As a result of research and development of PV technologies are main activity in the NPVC, a research result or progressive information from laboratory must be notified to other PV organisations. The NPVC must act as a national resource of PV technical information that can provide a single point of contact for question from the media, potential and users. Furthermore, PV international papers from any conferences or any PV journals need to be collected sequentially in this part of the centre. They are, for example, the conference record of the IEEE photovoltaic specialist conference, proceedings of the international conference European photovoltaic, solar energy conference. Furthermore,

there are some journals that must also be collected, such as journal of the international solar energy society, progress in Photovoltaics research and development, renewable energy journal and so on. Some official reports in high PV technology up date reference manual, and handbooks in specific PV topic should be collected as well. The NPVC must has a potential to bring people together through conferences and forum to share information and concerns, and can act as a conference organiser at local, national, international level. It depends on capability and authority in each country. The NPVC should provide a special meeting to discuss key needs of the PV industry, market development, systems both integration and applications development, including PV module manufacturing and applied research or exploratory development. Specialised scientists, engineers and researches from national labs can discuss their latest results of the works covering a range of PV topics at this meeting. It is important that the latest results of researching need to be produced to become a conference paper, a technical paper or a specific report that can present to public and/or to people who need to know the details like this. However, electronic communications and inter-linked databases for PV information are necessary to create through web-site news and must be download frequently.

3.4 PV consultancy

The objective of this activity is to act as an independent source for advice on the PV power systems design in different applications, including stand-alone PV system, grid-connected. Furthermore, the application of PV on building for architectural, technical, and financial point of view can be advised by the NPVC 's expert team, including up date PV technology on various researches. Another activity that the NPVC can undertake is to under contract to work a PV project with companies and agencies in the own country and overseas.

3.5 Training activities

At present, the training activities become necessary to develop on endogenous capability in photovoltaic cover a rang of disciplines. Technical training is required at many different levels, it is the most effective if developing countries concentrate their expertise in a PV centre. It would be the major receiver of high level training and the major provider of intermediate and low level training of indigenous personnel. In recent decades, training activities in some industrialised countries have been highly developed and extended to cover a much larger number of topics. Many of these activities provide new areas for research or apply the result of basic research to advanced industrial technologies. In general, training in the field of technology facilities: progressive strengthening of research centres with skilled staff and development of better scientific co-ordination. In addition, preparation of teams able to promote the use of

PV system and carry out joint actions with industrialists. Technical training programme can be delivered into 3 levels, namely high, intermediate and low level. Each training programme level needs the trainees in different background of knowledge. However, the main objective of training in developing countries is still the same that is to provide people or teams for PV technology and development in their countries.

3.5.1 High level training

This level is suitable for training to Master and Doctorate level in an industrialised country or some developing countries that have a high activity in PV technology. Training courses should be able to offer specific aspects of PV technology and/or research and development including PV system design, computer simulation and energy flow analysis, it depends on social and environmental aspects in each country. In the case of the trainees develop hands-on experience in putting together and maintaining PV systems in local conditions, but with little understanding. Whilst the second case develops a high degree of understanding of the principles of PV systems, but no hands-on experience under local conditions. To solve this problem the possible ways is to innovate Ph.D. programme involving both periods formal training and research. For training course on Ph.D. programme in home universities can be joined with the NPVC and requires the co-ordination of expert staff between the centre and university. Since university can play a key supporting role in almost every phase of technology development. However, the training on high level in developing countries still needs to help from of foreign aid. To be fully effective, the engineer who receives training abroad on high level, should be able to pass on his knowledge and skills to other individuals on his return home. The centre may provide a visiting professional training programme, country engineers usually spend 1 to 18 months that participating in experimental and analytical research project. The visiting professional will return home with knowledge of the current state of the technology and a personal and professional connection to the experts at the NPVC. This course, English is a language for communication that need to be used throughout the programme, because it is possible to work with many foreign PV experts at this training level.

3.5.2 Intermediate level training

As a result of PV is to be widely used, then many different people need to have an awareness and some knowledge of PV technology. To promote the widespread use of PV system in developing countries, trained people for industrial development and communication of PV systems is necessary. The aim of this course should be able to offer in various topics, such as PV system, solar cells, testing, fabricating and

packing. This course should be designed for people with some PV experience and systems. It covers the design and specification of several different applications for PV including larger system and solar cells manufacture. However, it is effective if the final year students at an undergraduate level in a university can attend in full course. The period of training depends on the time that the students can spend to work in the laboratory. Typically, 10 hours per week of experimental activity is required. The languages that should to be used are both English and native language, because some theoretical periods can teach by foreign PV expert and all of theoretical works as well as practical hands-on training using the facilities available at the NPVC can teach by home expert. Furthermore, an engineer who is successful on this training course should be able to pass on his knowledge and skills to other technicians in typical rural areas or should be able to acts as a leader for training in local or low level.

3.5.3 Low level training

Training course at this level should be able to provide different aspects of PV systems, such as PV water pumping, PV technique's workshop including installation and maintenance. The aim of this course is practical training for technicians and local people who are going to be technicians that must have a responsibility to investigate and maintenance PV systems within the rural villages. Moreover, skilled man power is also necessary to be trained. Generally, there is very often a shortage of laboratory and other equipment and often local production is not possible. In this case, the local government need to set up a regional PV training centre for providing an appropriate technical education and regional language may be communicated during training (if necessary). Basically, most technicians (skilled staff) have been living in typical rural villages that PV systems have been installed. It is possible to provide training with local language and at a level corresponding to the limited educational background of typical rural resident. The duration of course ranges from a few days to several weeks should be able to offer depending on the needs of the trainees, specifically designed covers for small groups should also be able to offer on request. The NPVC must provide information as a manual on the operation, inspection, troubleshooting, repair and maintenance of PV system to hand out the trainees who need to know how it works a how to maintenance and repair them.

The NPVC should provide technological training at all levels. It is also encouraging research, innovation and experimentation relating to programmes, methods and equipment for teaching whilst giving particular heed to the adaptation of the content and method to local conditions and requirements. However, it is a possible to develop and apply modern science and technological curriculum. It will be necessary for the key staff, the

teacher trainers and the curriculum development specialists, to be kept up to date.

4. CONCLUSIONS

The demand for photovoltaics application is growing at an unprecedented rate, the research and development of PV technology are growing as well. In addition, many PV systems have been installed worldwide. To help the photovoltaic industry maintain its competitive edge in many countries, the NPVC is needs to be established or be created. Since there are a number of the PV activities that the centre can conduct to promote for PV dissemination. They are research and development, collaborations, forum and information source, PV consultancy including training activity and serving as a single focal point for all the nation's capabilities in PV research and development. In order to PV technology's development is progress, the NPVC should also serve as the initial point of contact for potential investors, customers, manufactures and distributions interested in all aspects of PV technology and application. It can also connect them to the resource or information that they need quickly. So that the role of the NPVC is a very important implementation to promote the dissemination of photovoltaics.

However, a sustainable development of PV technologies in developing countries is difficult to achieve without the action of the central government. To establish the NPVC in the country is very necessary that can act as the conduit between policy formulation and the PV users. When the National Photovoltaic Centres are set up in developing countries, it seems that PV technology can be developed in these countries as good as they need.

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