CHAPTER 7

CONCLUSIONS AND FUTURE PROSPECTS
The importance of solar energy primarily for urban and peri-urban areas for sustainable development has been discussed in chapter 1. In this chapter, the active and passive solar techniques have been investigated and recommended in order to supply a sustainable energy in the residential and institutional buildings in urban and peri-urban areas. Active solar comprises mainly the solar thermal (for heating) and solar photovoltaics (for electricity) for a residential building. Passive solar mainly comprises the sustainable architecture of the building to harness the maximum possible solar gain ensuring a comfortable stay in the building. Further recommendations are provided by combining these two most efficient solar energy utilization techniques in the residential buildings. Such buildings that employ these two above mentioned techniques are known as “Green Buildings” or “Zero Energy Buildings”. The importance of solar energy systems has also been discussed. Then the discussion switches over to the solar photovoltaic (PV) systems by studying the concept and technologies behind the solar PV cells and systems. Various types of solar PV systems have also been discussed in this chapter. The brief introduction of Maximum Power Point Tracker (MPPT) has been discussed at the end of this chapter and various MPPT algorithms have been discussed in detail in chapter 2.

In chapter 2, we describe various MPPT techniques which are used to increase the efficiency of solar PV system. In this chapter, we mainly discuss about the seventeen different Maximum Power Point Tracking (MPPT) techniques viz. Perturb and Observe (P&O) based MPPT, Incremental conductance based MPPT, constant voltage based MPPT, Fractional short circuit current based MPPT, fractional open circuit based MPPT, Look up table based MPPT, Differentiation based MPPT, Estimated perturb-perturb based MPPT, Parasitic capacitance based MPPT, Load current/load voltage maximization based MPPT, DC link capacitor based MPPT, Linearization based MPPT, Fuzzy logic based MPPT, Neural network based MPPT, Particle swarm optimization (PSO) based MPPT and Hybrid MPPT. At last of this chapter, we analyze the MPPT selection on the basis of various performance parameters like no. of sensed parameters, control strategy, estimated cost, convergence speed, array dependency and implementation complexity etc.
We have proposed a modified P&O algorithm in chapter 3 which is designed by increasing the perturbation steps in traditional P&O method i.e. Advanced Perturbation and Observation (P&O) algorithm. In this algorithm, the perturbation steps are increased in order to closely precisely find and track the MPP with minimum possible tracking time. The proposed algorithm is designed in the form of a flowchart which describes the increased perturbation steps for reducing the wastage of power by rapidly find and tracking the MPPs of the solar PV system. We have presented the results obtained by simulating a boost converter in Gecko Circuits simulation software in chapter-3. The results show that the simulated boost converter provides the regulated output voltage and current which is a basic requirement to design a MPPT circuitry with a control algorithm implementation. The proposed algorithm (AP&O) is expected to be a simpler MPPT approach and would possess lesser implementation complexity. The subsequent implementation of MPPT control algorithms has been discussed with results in preceding chapters.

We have proposed differential power (dP) based algorithm in chapter 4. This algorithm is a new MPPT approach which is based upon the difference of two consecutive power levels (delivered by the solar PV system to the load) for three consecutive perturbation steps. Here the control algorithm discussed in the last chapter is elaborated and implemented to the designed MPPT circuitry. The theoretical analysis (as dP based MPPT algorithm) and further implementation (with MPPT circuitry) of this method is described in this chapter. Power based approach for finding (or tracking) the MPPs is found to be simpler and effective.

The simulation result obtained by us, implementing the proposed algorithm show that the operating point reaches to the MPP with higher convergence speed and hence minimizing the amount of waste power in order to optimize the efficiency of solar PV system.
In chapter 5, we have designed a hybrid control (HC) method by combining two classical methods i.e. P&O method and constant voltage method for different environmental conditions. In the case of rapidly changing environmental conditions, P&O method is employed while in steady environmental conditions, the proposed method switches over to constant voltage (CV) method. P&O method works on the principle of perturbation (change in solar PV voltage/current) by observing the appropriate change required in varying solar insolation and temperature. The constant voltage method works on the fact that the ratio of MPP voltage ($V_{MPP}$) to open circuit voltage ($V_{OC}$) is constant and this value usually in the range of 0.78 to 0.92. This method is also said to be fractional open circuit voltage method. The result obtained by employing the proposed hybrid algorithm indicates the better stability of operating point which superimposes to MPP very rapidly and consequently the efficient operation of MPPT for efficiency maximization of solar PV system is achieved. This method also provides the faster regulation (of electrical parameters) and hence higher stability of operation of MPP tracking in solar PV system. As, two simple MPPT methods are combined to design a more effective and flexible MPPT technique, this method is termed as Hybrid control method which also reduces the implementation complexity of the overall MPPT circuitry.

In chapter-6; Fill factor (FF) and Maximum Power Angle (MPA) based two new MPPT techniques have been discussed. These two techniques provide a new direction in the area MPPT. By the linear relationship between FF and $V_{OC}$ as represented by the given empirical formula, it is possible to design the control algorithm for an improved MPPT. The results show the typical variation of FF with the $V_{OC}$ which is proved to be the strong platform for designing of an improved and efficient MPPT for solar PV system with a cost effective approach. The proposed approach has an advantage that it can be employed to MPPT by the prior information about solar PV characteristics. Maximum power angle based approach for a modified MPPT is also designed and analyzed in chapter 6. This approach utilizes the available characteristic curves of solar PV module to search and track the MPP at particular instant of time of the day. This approach is a graphical
approach which uses the simple mathematical theorem i.e. Pythagoras theorem to find the MPP angle from which the MPP can be easily tracked. In the proposed technique, the sensor requirement is reduced in order to decrease the cost of the overall MPPT system and simpler implementation of control strategy. The control flow of the proposed approach is represented with flowchart drawn. These two techniques (FF and MPA based MPPT) are simpler cost effective approaches in designing of MPPTs for higher efficiencies of solar PV system as the sensor and hardware requirements are substantially reduced in these techniques due to their graphical, mathematical and analytical nature.

Thus various existing and new control strategies have been described in terms of different performance parameters like efficiency, cost involved and complexity level. It is also observed that every MPPT is not suitable for every application. But somewhere (like HEVs or Grid connected solar PV systems) it is needed to have the more accurate and highly efficient MPPT technique which is expensive while in some applications (like standalone residential solar PV system or small solar power plant), the cheaper and moderately efficient and accurate but simple MPPT can be employed for an efficient operation of solar PV system.

Some points, described as a future prospective of the work done so far and study of various aspects of MPPT for an enhanced efficiency of solar PV system, are as follows:

- Some more hybrid MPPT techniques may be explored by combining two or more control methods in order to further increase the efficiency of solar PV system in varying insolation and other environmental conditions.

- The efficiency of solar PV system can be improved by using the combination of tracking of MPPs (on characteristic curve of PV cell) as well as the physical tracking of Sun by PV panels.
Researchers (MIT, USA; University of Wisconsin-Madison, USA; RWTH Aachen University, Germany and Heriot-Watt University, UK) are also working on the sunflower inspired physical tracking of sun by solar PV panels which will be prove to be a breakthrough research in the area of nature inspired solar photovoltaics in order to further optimize the efficiency of solar PV system.