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Green Energy-assisted Frost Prevention: A Conceptual Framework

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Abstract

Solar photovoltaics (PV) is a popular method of green energy-based electricity generation for regions with rich solar radiation. In this paper, we introduce a conceptual framework where PV can be used for multi-purposes: electricity generation and frost prevention, specifically for frost prevention of apricot orchards. After introduction of the conceptual framework, the system modelling, optimization, and control/automation research challenges for such a multi-purpose use are summarized. This paper targets at opening a new application area and the associated research rooms for PV systems.

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Keywords: photovoltaics, frost prevention, horticulture, green energy

1. Introduction

Climate change, the necessity of replacing decreasing finite fossil-based energy resources with renewable ones, and the ever-increasing search for energy-efficient and sustainable systems resulted in focus on renewable energy among which solar energy is a good option [1,2]. Solar energy can be obtained through thermal solar panels or PV systems. For regions with rich solar radiation intensities, PV systems can generate a considerable amount of electrical energy. PV systems have attained a considerable attention, and an extensive number of studies on modelling [3,4,5], control [6,7,8] and optimization of such systems [9,10,11] have appeared in the open literature.

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In this paper, a conceptual framework for a new application area of multi-purpose PV systems is proposed: electricity generation coupled with frost prevention for large-scale apricot orchards in a region of Turkey famous for apricot production. The produced electricity by the PV system will be used to heat air and low it on apricot trees during the frost periods. Turkey is one of the leading countries in the world in apricot production as shown in Figure 1, and this production is dominantly done in Malatya city of Turkey as shown in Figures 2. However, apricot is a fruit which is very sensitive to frost during its flowering period and the short period after flowering, which cover the March-April months. In general, the flowers of apricots wilt for temperatures in the range -10 °C to 0 °C, but this also depends on other climate conditions (wind, humidity, etc.). However, the main climatic parameter affecting the apricot buds flowering is the occurrence of freezing temperatures.

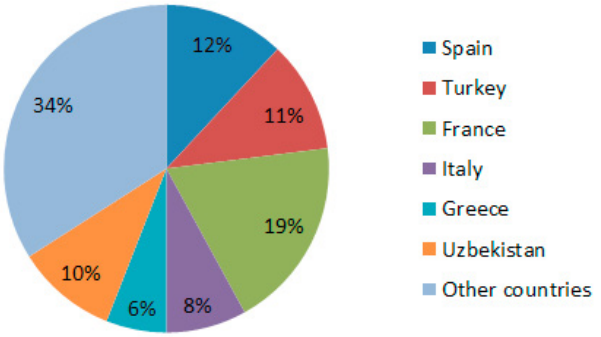

Fig. 1. Main fresh apricot producer countries [12].

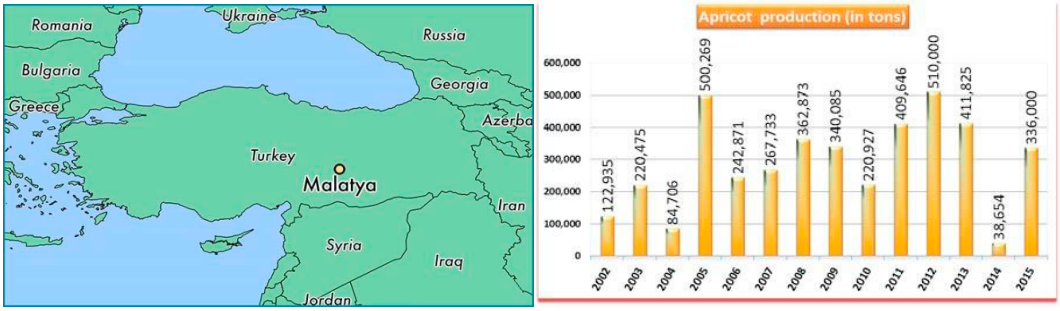

Fig. 2. left: Malatya, apricot capital in Turkey, right: Apricot production in the last decade in Malatya [13].

Minimum temperature levels (which may cause frost) during bud period, flowering period, or early fruit developing periods have strong negative impacts on apricot yield [14,15]. Hence, spring frosts put the apricot growers under a big stress. Based on the statistics of previous years, frost occurs every two to three years during March-April months [16]. When frost happens, it can cause significant apricot yield loses. Just as an example, the frost phenomena in 2014, with only 2 occurrences of temperature below 0 °C, caused around 95 % of yield loss in Malatya. The apricot production amounts in Malatya over the last decade are given in Figure 2, right. As observed, in some years the yield is very low. These are years where frost has caused significant yield loss.

Table I shows the number of times the temperature levels were below 0 °C over the last two decades for the Malatya region of Turkey in the spring season. From the presented data, one can see that so far every year (except 2001) at least one time temperature dropped below 0 °C during March- April months, which is potentially enough to cause frost. It is important to know that withering of apricot buds/flowers due to frost is dependent not only on temperature levels below zero, but also on humidity, wind, whether the period is budding, flowering or early fruit period, cultivar type, the tree, etc. However, still temperature levels below 0 °C are dangerous and are the main parameters for yield loss due to frost.