Model Predictive Control Based MPPT Using Quasi-Admittance converters for photovoltaic system

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Abstract

The use of renewable energy sources is on the increase because of the intense energy crisis in the world today. Solar energy is one of the enormous resource in tropical countries. The main hitch for the penetration of the PV systems is their low efficiency and high capital cost. This project uses the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system. A new topology called “quasi-Y-source dc-dc converter” is presented in this project. The new topology obtains continuous current from the source which is important for many renewable resources now a days. It also used to achieve maximum efficiency for various solar irradiance level.

Keywords– Model Predictive Control, Quasi-Y Source Converter, MPPT.

I. INTRODUCTION

The 21st century is mostly concerned with the usage of Renewable energy resources. The mostly used renewable energy is solar energy, which is available abundantly in tropical countries like INDIA. The dependence on fossil fuel has reduced a lot in the recent years. The government has been providing various concession on generating solar power domestically. The main issue during the present generation is its efficiency of generation based on their capital investment. This issue is universally given as “By what technique the power can be efficiently generated”. Here the MPPT technique is proposed which applies the new control method known as “Model predictive control”. This method of control is based on the reference value and the predicted value from the prescribed model. The real time use of this method is the GPS used in mobile phones. This technique has a simplified design process and a enhanced disturbance rejection.

Maximum Power Point Tracking is an electronic system that operates the Photovoltaic (PV) modules to produce all the power they are capable of. A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Now-a-days the conversion of electrical energy from any form of energy is the most researchable topic. Since the source is from PV panel the DC-DC boost up converters are used. The latest converter that is proposed here is the Quasi-Admittance Source Converter. It inherits all the properties of Y-Source converter and in addition, it draws a continuous input current from the source. The second stage of the circuit consist of a simple DC-AC inverter which is connected to the load. The block diagram of the above-mentioned project is given in figure below.

II. BASIC CONCEPTS OF PHOTOVOLTAIC SYSTEMS

The term “Photovoltaic “refers to the conversion of solar radiation directly in to electrical energy. This is due to the photovoltaic cell made of silicon. When it comes to photovoltaic system it consists of a DC-AC inverter which is connected to the load. Now-a-days a DC-DC boost converters are used to boost the input voltage and given to the inverter. The maximum power can be obtained from the system using the technique called “Maximum Power Point
Tracking”. This technique uses algorithm to track the maximum power from the PV source. The power extracted from the PV source can be controlled by the controlling the conduction state of the semiconductors in the PV array.

A MPPT technique gives the basic logic for the control of conduction state of duty cycle. The Perturb and Observe (P&O) and Incremental Conductance (Inc Cond), are the most common methods that are being implemented in last decade. Though, both methods suffer from the fixed step size problem. For a shorter step size, the solution is assured but the set-up time is increased. So, a new method called “Model predictive control” is applied here. This method uses a predictive value for the conduction of duty cycle.

III. QUASI Y-SOURCE CONVERTER

The design of intermediate step-up dc–dc converter with a continuous input current and wide range of voltage gain is one of the most challenging requirements faced by many distributed power generation and conditioning systems. To meet this challenging requirement, various admittance networks have been developed to provide an efficient means of converting power with a wide range of voltage gain. The Y-source network has earlier been tested as a dc–dc converter, whose schematic is shown in Fig. 1. Its current drawn from the source is, however, discontinuous or pulsating between zero and a finite value, which is certainly not appropriate for most renewable sources. A simple modification to smoothen the current is presented in by using an additional input capacitor with the T-source network. The same technique can be applied to the Y-source network like shown in Fig. 2. The modified network can indeed draw a continuous input current, but only when certain capacitance ratio between $C_1$ and $C_2$ is accurately set, and parasitic resistances minimized as much as possible. Another approach for smoothing the input current is to be considered, which can be achieved by adding an input inductor with a capacitor. These added components, when used with the Y-source network, gives the newly proposed dc–dc converter shown in Fig. 3. The proposed new converter is a DC-DC voltage boost up converter which draws a continuous input current from the source. It can handle a wide range of input voltage, without increasing the voltage stresses uninterrupted by its components. The proposed quasi-y converter is thus more suitable for renewable power conditioning systems. The Fig. 4 gives the equivalent circuit of the proposed converter.
The Simulink model Quasi Y-Source Converter is given in Fig. 5. The Table 1 gives the specifications of the elements used in this Simulink model.

### Table 1 Simulation Parameters [Quasi-Y]

<table>
<thead>
<tr>
<th>COMPONENTS</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>10 ohms</td>
</tr>
<tr>
<td>L1</td>
<td>16.6e-3 H</td>
</tr>
<tr>
<td>C, C1, C2</td>
<td>1000e-6, 470e-6, 450e-6 F</td>
</tr>
</tbody>
</table>

### V. Model Predictive Control

The proposed MPC based MPPT algorithm tracks the MPP of the PV array module by changing the PV voltage to the voltage at MPP through the following steps:

**Step 1** - The algorithm derives the two possible future PV voltage values at time k+1:

\[ V_{pv}(k+1)^1 = V_{pv}(k) + \Delta \]

\[ V_{pv}(k+1)^2 = V_{pv}(k) + \Delta V \]
Step 2- In this paper, the following update law for \( \Delta V \) is proposed,
\[
\Delta V = |V_{PV}^{avg}(k-1) - V_{PV}(k)|
\]
where \( V_{PV}^{avg}(k+1) \) is the predicted average PV voltage for the next sample time (k+1).

Step 3- In this step the algorithm calculates (predicts) the power that would be drawn from the PV module if the PV voltage were to shift to either of the two possible values of \( V_{PV}(k+1)^1 \) and \( V_{PV}(k+1)^2 \) in the next sample time.

Step 4- To compute the generated power, the algorithm requires the value of the local P-V characteristic of the module around the operating point of \( V_{PV}(k) \).

Step 5- A digital observer is used to produce the required value for the predictions. The employed estimator equations are,
\[
R_{eq}(k) = -\frac{V_{PV}(k) - V_{PV}(k-1)}{I_{PV}(k) - I_{PV}(k-1)} \\
V_{eq} = V_{PV}(k) + R_{eq}(k) I_{PV}(k)
\]
where \( V_{PV}(k-1) \) and \( I_{PV}(k-1) \) are the values of the PV module voltage and current from the previous sampling time.

Step 6- Estimating the equivalent resistance and voltage of the PV module, the two possible values for the generated power in the next sampling time can be easily predicted from,
\[
P_{PV}(k+1)^{(1,2)} = V_{PV}(k+1)^{(1,2)} \times I_{PV}(k+1)^{(1,2)}
\]
where,
\[
I_{PV}(k+1)^{(1,2)} = \frac{-V_{eq}(k) - V_{PV}(k+1)^{(1,2)}}{I_{PV}(k) - I_{PV}(k-1)}
\]

Step 7- Now the predicted power for the two different cases are used to evaluate the following cost function,
\[
(J)^{(1,2)} = P_{PV}(k+1)^{(1,2)} - P_{PV}(k)
\]
the generated power in further steps, the predicted power, or \( P_{PV}(k+1)^1 \) and \( P_{PV}(k+1)^2 \) will result in a larger value of \( J \). The desirable value of the PV voltage for the next step is denoted as hereinafter.

Step 8- The values of M and D are generated from the PID controller. The gain can be realized using a unique combination of M and D that will result in the minimum voltage stress on the switches. This combination can be found:
\[
M = G \\
D = 0
\]
for gain less than or equal to one, and from,
\[
M = \frac{G}{2G-1} \\
D = 1-M
\]
for the gain, more than one.
VI. SIMULINK MODEL

TABLE 1 SIMULATION PARAMETERS [PV module]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV array Power rating (W)</td>
<td>46.30</td>
</tr>
<tr>
<td>Input voltage (V)</td>
<td>282.58</td>
</tr>
<tr>
<td>Input current (A)</td>
<td>0.16</td>
</tr>
<tr>
<td>Irradiance level (W/m²)</td>
<td>800–1000</td>
</tr>
</tbody>
</table>

Fig. 6 Simulink Model of Proposed System

VII. SIMULATION RESULTS

FIGURE 7 PV initial current at the first iteration of MPPT
FIGURE 8 PV initial power at the first iteration of the MPPT

FIGURE 9 PV initial voltage at the first iteration of the MPPT
VIII. CONCLUSION
This project has successfully boosted up the voltage of the PV module using the Quasi-Y converter. The Maximum power point has been tracked using the Model Predictive Control technique. The power generated from the inverter is used to satisfy the rated power demand. Experimental and simulation results confirms the efficiency of the controller, exposing good reference-tracking and disturbance reduction characteristics. Compared to the conventional control of dc-link voltage, control of the capacitor voltage quasi-Y-source network for voltage boost is preferred. This is mainly because, the capacitor voltage can be set to a certain value and the minimized voltage stress on switching devices can be achieved.

REFERENCES
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