Abstract—This paper presents a new approach based on the genetic algorithm is used to perform a constrained tuning technique for the PID parameters to optimize the power output of solar panel. The dynamic model is used to design the controller parameters of the conventional PID controller. The dynamics of the dc to dc converter is non linear, therefore, it is hard to derive desirable performance. Hence, Genetic algorithm is used to optimize the control parameters of boost converter. In order to obtain the fitness of an individual, Simulink model of the boost converter is designed and the genetic algorithm is programmed to search the optimal control parameters by manuscript file of the matlab.

Keywords—Boost converter, Genetic algorithm, PID controller, Ziegler Nichols Method.

I. INTRODUCTION

The energy requirement of the world is ever increasing. The increasing energy demands put a lot of pressure on the conventional energy sources (oil, gas and coal). But the fossil fuel-based energy sources are limited in quantity and also cause environmental pollution. The negative effects of the conventional energy sources can be overcome by making use of sun’s energy. It is an everlasting, clean renewable energy source and no potential damage to the environment. But there are significant challenges to be overcome in order to make use of clean energy. They are energy cost, energy fluctuations, location dependency and high investment requirement. The changes in insulation conditions severely affect the efficiency and output power of the PV modules [1].

A great deal of research has been done to improve the efficiency of the PV modules. A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers [4]-[8].

PV modules still have relatively low conversion efficiency therefore, controlling maximum power point tracking (MPPT) for the solar array is essential in a PV system. The amount of power generated by a PV depends on the operating voltage of the array. A PV’s maximum power point (MPP) varies with solar insulation and temperature [4].

GAs are promising methods for solving difficult technological problems, and for machine learning. In this paper genetic algorithm is used to calculate the optimal control parameters of PID controller. Genetic algorithm is a computational procedure that mimics the natural process of evolution [3]-[4]. It works by evolving a population of solutions over a number of generations. For each generation, solutions are selected from the population based on the fitness value. These solutions by crossover (merging previous solutions) and by mutation (modifying the solutions) generate new population. Since it searches many peaks in parallel, the trapping at local minima is avoided [10]-[12].

The following section 2 formulates the entire configuration of a boost converter with photovoltaic modeling. The focus of section 3 is on different tuning techniques of PID controller and its implementation. In section 4, simulation results of the corresponding system are obtained and compared.

II. SYSTEM CONFIGURATIONS

Fig.1 System configuration diagram

Genetics algorithm is embedded in the feedback compensation circuit design and it is performed in the frequency domain and aided by Bode plots, the design essentially involves positioning of poles and zeros of the selected compensation circuit to compensate the undesirable characteristics of a power stage. The voltage reference $V_{\text{ref}}$ signal is generated from the MPPT controller. In the proposed...
method the boost converter serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the PV array. The entire system configuration is shown in figure 1.

A. Photovoltaic Cell Modeling

An ideal solar cell can be considered as a current source wherein the current produced by the solar cell is proportional to the solar irradiation falling on it. Though the practical behavior of a cell is deviated from ideal due to the optical and the electrical losses, yet in order to develop an electrical equivalent circuit model for solar cell, appropriate components should be added with ideal current source. An electrical circuit representing a solar cell is shown in figure 2. The optical loss is represented by the current source itself, where the generated current \( I_{\text{ph}} \) is proportional to the light input. The recombination losses are represented by the diode connected parallel to the current source, but in the reverse direction. The ohmic losses in the cell occur due to the series and shunt resistance denoted by \( R_s \) and \( R_{sh} \) respectively [1].

Fig. 2. Simplified-equivalent circuit of photovoltaic cell.

Applying Kirchoff’s voltage law to the node where \( I_{\text{ph}} \), diode, \( R_p \) and \( R_s \) meet, we get

\[
I_{\text{ph}} = I_D + IR_p + I
\]

We get the following equation for the photovoltaic current:

\[
I = I_{\text{ph}} - I_D - IR_p
\]

\[
I = I_{\text{ph}} - I_D - IR_p \left[ \exp \left( \frac{V + IR_p}{kT} \right) - 1 \right] - \frac{V + IR_p}{R_p}
\]

Where, \( I_{\text{ph}} \) is the Insolation current, \( I \) is the Cell current, \( I_D \) is the Reverse saturation current, \( V \) is the Cell voltage, \( R_s \) is the Series resistance, \( R_p \) is the Parallel resistance, \( V_T \) is the Thermal voltage \((kT/q)\), \( K \) is the Boltzman constant, \( T \) is the Temperature in Kelvin and \( q \) is the Charge of an electron.

B. Boost Converter Design

The boost converter is capable of producing a dc output voltage \( (V_o) \) greater in magnitude than the dc input voltage \( (V_i) \). The circuit topology for a boost converter is as shown in figure 3.

The conversion ratio is given by the following expression:

\[
\frac{V_o}{V_i} = \frac{I_D}{I_D} = \frac{1}{1-d} \quad (4)
\]

\[
d = \frac{T_{\text{on}}}{T} \quad \text{where } I_D \text{ the input current of the converter and } T = T_{\text{on}} + T_{\text{off}}, \text{ with its range } 1 \geq d \geq 0.
\]

Knowing the \( V_a \) and \( I_a \), we can find the input resistance \( R_{\text{in}} \) of the converter. This is given by

\[
R_{\text{in}} = \frac{V_a}{I_a} = R_o (1 - d)^2 \quad (5)
\]

Here, \( R_{\text{in}} \) varies from \( R_o \) to 0 and \( d \) varies from 0 to 1. The transfer function of the boost converter is

\[
\frac{V_o}{V_i} = \frac{1}{(1-d)^2} \left( 1 + \frac{L}{R(1-d)^2} s + \frac{L^2}{(1-d)^2} s^2 \right) \quad (6)
\]

C. MPPT Algorithm

The boost converter circuit diagram is shown in figure 3.

The boost converter is capable of producing a dc output voltage \( (V_o) \) greater in magnitude than the dc input voltage \( (V_i) \). The circuit topology for a boost converter is as shown in figure 3.

The conversion ratio is given by the following expression:

\[
\frac{V_o}{V_i} = \frac{I_D}{I_D} = \frac{1}{1-d} \quad (4)
\]

\[
d = \frac{T_{\text{on}}}{T} \quad \text{where } I_D \text{ the input current of the converter and } T = T_{\text{on}} + T_{\text{off}}, \text{ with its range } 1 \geq d \geq 0.
\]

Knowing the \( V_a \) and \( I_a \), we can find the input resistance \( R_{\text{in}} \) of the converter. This is given by

\[
R_{\text{in}} = \frac{V_a}{I_a} = R_o (1 - d)^2 \quad (5)
\]

Here, \( R_{\text{in}} \) varies from \( R_o \) to 0 and \( d \) varies from 0 to 1. The transfer function of the boost converter is

\[
\frac{V_o}{V_i} = \frac{1}{(1-d)^2} \left( 1 + \frac{L}{R(1-d)^2} s + \frac{L^2}{(1-d)^2} s^2 \right) \quad (6)
\]
Algorithms for MPPT are various types of schemes that are implemented for obtaining maximum power transfer. Some of the popular schemes are the hill climbing method, incremental conductance method, constant voltage method etc. Perhaps, the most popular algorithm is the perturb and observe (hill climbing) method and its flow chart is shown in figure.4. It is applied by perturbing the duty cycle D at regular intervals and by recording the resulting array current and voltage values, thereby obtaining the power. Once the power is known, a check for the slope of the PV curve or the operating region is carried out and then the change in D is effected in a direction so that the operating point approaches MPP on the power voltage characteristic [9].

The transfer function of the PID controller is represented by
\[ G_c(s) = K_p(1 + \frac{1}{T_i} + T_d s) \]  

The PID parameters can be calculated as \( K_p = 0.05 \), \( K_i = 53 \) and \( K_d = 0.004675 \).

The total response of the system can be calculated as follow
\[ R(s) = \frac{0.004675s^2 + 0.05s + 53}{1953.8112 \times 10^{-12}s^3 + 4.69 \times 10^{-7}s^2 + 0.504675s + 53} \]

III. TUNING TECHNIQUES OF PID CONTROLLER

A. Ziegler Nichols Method

The Ziegler-Nichols Closed Loop method is one of the more common methods used to tune control loops. The Ziegler–Nichols tuning method is a heuristic method of tuning a PID controller. It is performed by setting the \( I \) (integral) and \( D \) (derivative) gains to zero.

- Set up the system with proportional only control and add a disturbance.
- Alter the gain of the process until you obtain the smallest gain which gives constant amplitude oscillations. This gain is called the Ultimate Gain, \( K_u \).
- Now evaluate the period of these constant oscillations. This is known as the Ultimate Period, \( P_u \).

<table>
<thead>
<tr>
<th>Controller</th>
<th>( K_p )</th>
<th>( T_i )</th>
<th>( T_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>( K_u/2 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>( K_u/2.2 )</td>
<td>( P_u/1.2 )</td>
<td></td>
</tr>
<tr>
<td>PID</td>
<td>( K_u/1.7 )</td>
<td>( P_u/2 )</td>
<td>( P_u/8 )</td>
</tr>
</tbody>
</table>

Table.I prescribes the type of controller used for the Ziegler and Nichols method and it is based on the values of \( P_u \) and \( K_u \).

Genetics Algorithm Based MPPT Controller for Photovoltaic System
meaning that the same chromosome can be selected more than once to become a parent.

b. With probability \( p_c \) (the “crossover probability” or “crossover rate”), cross over the pair at a randomly chosen point (chosen with uniform probability) to form two offspring. If no crossover takes place, form two offspring that are exact copies of their respective parents. (Note that here the crossover rate is defined to be the probability that two parents will cross over in a single point. There are also “multi-point crossover” versions of the GA in which the crossover rate for a pair of parents is the number of points at which a crossover takes place.)

c. Mutate the two offspring at each locus with probability \( p_m \) (the mutation probability or mutation rate), and place the resulting chromosomes in the new population. If \( n \) is odd, one new population member can be discarded at random.

4. Replace the current population with the new population.

5. Go to step 2.

C. Realization of GA based PID controller

The block diagram of the entire system is shown in Fig.5. The system output is denoted by \( R(s) \), its input is denoted by \( C(s) \), and the reference input to the PID controller is denoted by \( C(s) \). GA can be applied to the tuning of PID controller gains to ensure optimal control performance at nominal operating conditions.

The tuning parameter for the genetics algorithm is given in Table 2. The overall transfer function of the entire system is

\[
R(s) = \frac{K_d s^2 + K_p s + K_i}{(1-d)^2 s^2 + \left(\frac{L}{R(1-d)}\right)s^2 + \left(K_p + (1-d)\right)s + K_i}
\]  

(9)

The optimal GA tuned PID parameters can be calculated as \( K_p = 0.0233 \), \( K_i = 24.6386 \) and \( K_d = 0.002 \). After applying the tuning parameters to GA the PID controllers can be easily tuned and thus system performance can be improved.

\[
R(s) = \frac{0.002s^2 + 0.0233s + 24.6386}{1953.8112 \times 10^{-12}s^3 + 15.314 \times 10^{-6}s^2 + 0.5233s + 24.6386}
\]  

(10)

IV. SIMULATION RESULTS

The PV modules are needed to be connected together in series or parallel in order to achieve higher power output. These combinations of PV modules is called ‘PV array’. The PV module is implemented with sim power system blocks and it’s shown in figure.6.

![SIMULINK model of PV array](image)

Fig.6. SIMULINK model of PV array

The sub module of PV array for determining the PV cell output voltage is shown in figure.7. The closed loop response of zigler nichol’s method is shown in figure.8. The GA based PID tuning values of \( K_p, K_i, K_d \) and gain values are illustrated in the figure.9.

<table>
<thead>
<tr>
<th>TABLE II</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENETIC ALGORITHM PARAMETERS</td>
</tr>
<tr>
<td>GA Property</td>
</tr>
<tr>
<td>Population Size</td>
</tr>
<tr>
<td>Maximum Number of Generations</td>
</tr>
<tr>
<td>Performance Index/Fitness Function</td>
</tr>
<tr>
<td>Selection Method</td>
</tr>
<tr>
<td>Crossover Method</td>
</tr>
<tr>
<td>Crossover Probability</td>
</tr>
<tr>
<td>Mutation Method</td>
</tr>
<tr>
<td>Mutation Probability</td>
</tr>
</tbody>
</table>

1162

Mallika and Saravanakumar

Genetics Algorithm Based MPPT Controller for Photovoltaic System
The response of the system with GA based PID controller looks stable compared to conventional approach. The comparison of different tuning techniques is given in Table 3.

<table>
<thead>
<tr>
<th>Tuning Parameters</th>
<th>ZN Method</th>
<th>Genetic Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kp</td>
<td>0.05</td>
<td>0.0233</td>
</tr>
<tr>
<td>Ki</td>
<td>53.12</td>
<td>24.6386</td>
</tr>
<tr>
<td>Kd</td>
<td>0.004675</td>
<td>0.0020</td>
</tr>
<tr>
<td>Maximum overshoot</td>
<td>0.509</td>
<td>0.501</td>
</tr>
<tr>
<td>Rise time (sec)</td>
<td>0.0786</td>
<td>0.0255</td>
</tr>
<tr>
<td>Settling time (sec)</td>
<td>0.0963</td>
<td>0.0378</td>
</tr>
</tbody>
</table>

V. CONCLUSION

The GA based MPPT controller for solar system is implemented in MATLAB/SIMULINK software and its performance is compared with conventional techniques. The designed PID with GA has much faster response than response of the conventional method. The conventional method response is good, however the GA designed PID is much better in terms of the rise time and the settling time than the conventional method. In future GA based PID controller will be implemented in grid connected solar system. These configurations may also be applied in distributed power generation involving wind mills, fuel cells etc.

ACKNOWLEDGMENT

Authors acknowledge the support, encouragement and facilities provided by the School of Electrical Engineering and management of VIT University, Vellore, Tamilnadu, India in carryout the presented research work. And also thank the IIT Bombay, Department of Energy Science and Engineering for provided the solar kit.
References


