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Isolated Wind-Solar Hybrid Power System Analysis

KEYWORDS: Isolated hybrid power system, PV, Solar power generation, Fuzzy logic based controller.

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ABSTRACT *Electricity is a quantity, commodity that is required from charging a phone to running a factory. With the ever growing demand of electricity renewable energy resources such as wind energy have emerged as an efficient way of generating electricity. The self-excited induction generator (SEIG) is the best suited isolated generation system due to its simple and robust construction, reduced unit cost and easy maintenance.. Photo-voltaic power is also another promising energy source. Wind power and PV power are complimentary because strong winds are mostly to occur during night time and cloudy days whereas sunny days are often come with weak winds.*

Hence, Wind-Solar hybrid generation system can offer higher reliability to maintain continuous power output than other individual power generation systems. The stand alone wind- solar hybrid generation system is valuable to use. Therefore it is important to study the performance of standalone wind-solar hybrid generation system under steady-state and dynamic conditions for the optimum utilization of its meritorious features. In this paper a simple and generalized fuzzy logic based intelligent controller is proposed, which is suitable for autonomous operation of solar energy conversion or for isolated hybrid energy conversion.

Introduction

Now widely recognized and used fossils fuels and other conventional resources presently being used in the generation of electrical energy, may not be either sufficient or suitable to keep pace with ever increasing world demand for electrical energy.

Solar energy is the most abundant and constant stream of energy. It is available directly (solar insulation). Especially in countries like India where the government is facing oil crunch, the tapping of PV energy which is available (in abundance) throughout the year will be very important.

The working principle of solar panel is that when light radiation falls on a p-n junction, a voltage is generated. [1] The primary power comes from the striking photons. The use of solar insolation to generate electricity is increasing constantly over the past few years. As the world's electricity demand is increasing, the use of photovoltaic system is attracting more and more attention of power system planners.

Among the renewable energy sources, wind energy also seems to be prominent and quite promising for electric power generation. Wind energy conversion has been found economically comparable to the cost of fossil fuels which are rising at a much faster rate. Therefore, the study of induction generators has regained importance, as they are particularly suitable for wind and small hydro power plants.

The advantageous features of induction generators are less maintenance, operational simplicity, self-protection against faults, brush less and rugged construction.[2]

The capability to generate power at varying speed is the feature of induction generator which helps it to operate in self excited/ isolated mode to supply far flung and remote areas where extension of grid is not economically feasible in order to fulfill the increased local power requirements.

The system based on either wind or solar energy is unreliable due to seasonal and diurnal variation of these resources.

It is well known that the wind power and PV power are complementary to some extent since strong winds are mostly occur during the night time and cloudy days whereas sunny days are often calm with weak wind.

Hence, a PV-wind hybrid generation system can offer higher reliability to maintain continuous power output than any other individual power generation system. In those remote or isolated areas, the stand-alone PV-wind hybrid generation system is particularly valuable and attractive.[4]

Therefore, it is important to study the performance the stand-alone PV-wind hybrid generation system under steady-state and dynamic condition for the optimum utilization of its meritorious features.

Ease of Use

To develop a generalized fuzzy logic based intelligent controller, which is suitable for autonomous operation of solar energy conversion as well as isolated hybrid energy conversion employing wind and solar systems. Moreover a solar based inverter has to be developed along with fuzzy based MPPT controller which provides the reactive power requirement (in addition to the fixed capacitance) of induction generators under varying speed and loads in order to maintain the load voltage almost constant.

Therefore an attempt is made to design a generalized fuzzy logic controller for isolated hybrid scheme employing solar and wind energy conversion system.

To develop a fuzzy logic based MPPT controller for effective utilization of photovoltaic energy and to adopt it in hybrid generation employing wind-solar energy conversion.

To analyze dynamic and steady state performance of three

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phase and single phase self-excited induction generators and to adopt them in hybrid generation employing wind-solar energy conversion.[5]

To develop a fuzzy a logic based controller for a stand-alone hybrid generation system using wind (three phase self-excited induction generator) and photovoltaic energy to achieve better voltage regulation, under steady state and dynamic conditions, for varying irradiation, wind speed and load.

To develop a fuzzy logic based controller for a stand-alone hybrid generation (with Vienna Rectifier) system using wind (three phase self-excited induction generator) and solar energy to achieve better voltage regulation, under steady state and dynamic conditions for varying irradiation, wind speed and load.

ANALYSIS OF PHOTO-VOLTAIC ARRAY

Solar energy generation is sustainable with less carbon emissions. The output power of a PV array varies according to the sunlight conditions such as solar irradiations, shading and temperature. To obtain maximum power from photovoltaic array, photovoltaic power system usually requires maximum power point tracking (MPPT) controller.[3]

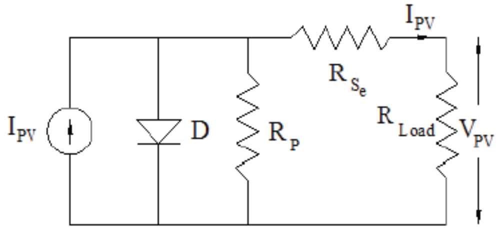
Various approaches have been reported to implement MPPT such as perturb and observe (P&O) method the incremental conductance method, constant voltage method and short-circuit current method. Using these methods, the maximum power point can be found for specified solar radiation and temperature condition but they display oscillatory behavior around the maximum power point under normal operating conditions.

The proposed intelligent fuzzy logic process comprises of expert knowledge which extracts maximum power from a PV module under varying solar irradiation, temperature and load conditions. The shape of the membership functions of the fuzzy logic controller can also be adjusted such that the gap between

the operating point and maximum power point can be optimized. The fuzzy logic controller based results are compared with the conventional techniques such as P&O and PI controllers which validate it's merits. An experimental setup of the proposed scheme has been built and the results obtained on a PV array of 74.8W, 21.2V, 4.4A, (15 panels connected in series).

Modeling of a PV Array

A PV cell can be represented by an equivalent circuit of single diode model [131] as shown in Fig. 2.1. The characteristics of this PV cell can be obtained using standard equation (2.1).



IPV = photovoltaic current

IO = saturation current

Vt = NS k T/q, thermal voltage of array

Ns = Number of cells connected in series

T = actual temperature

k = Boltzmann constant

q = electron charge

RSe = equivalent series resistance of the array

RP = equivalent parallel resistance of the array

ad = diode ideality constant

From the general I-V characteristic of the practical photovoltaic device, one can observe that the series resistance Rse value will dominate in the voltage source region and the parallel resistance RP value will dominate in the current source region of operation.

The general equation of a PV cell describes the relationship between current and voltage of the cell. Since the value of shunt resistance RP is high compared to value of series resistance Rse the current through the parallel resistance can be neglected. The light generated current of the photovoltaic cell depends linearly on the solar irradiation and is also influenced by the temperature given by the equation.[5]

$$I_{PV} = \left[I_{PV,n} + K_I \, \Delta_T\right] \frac{G}{G_n}$$

$I_{PV,n}$= light generated current at nominal condition

(250C and 1000 W/ m2)

T = T - Tn

T = actual temperature [K]

Tn = nominal temperature [K]

KI = current coefficient

G = irradiation on the device surface [W/m2]

Gn = nominal irradiation

It can be noted that the equivalent series and parallel resistance are directly proportional to the number of series modules and inversely proportional to the number of parallel modules respectively.

Fuzzy Logic MPPT Controller

The conventional PI controllers are fixed-gain feedback controllers. Therefore they cannot compensate the parameter variations in the process and cannot adapt changes in the environment. PI-controlled system is less responsive to real and relatively fast alterations in state and so the system will be slower to reach the set point.

The block diagram of fuzzy logic controller (FLC) is shown in Figure

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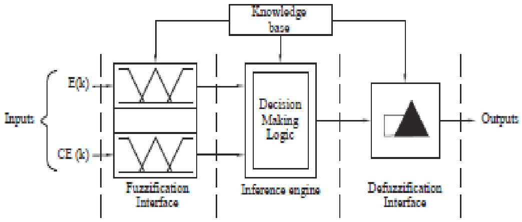
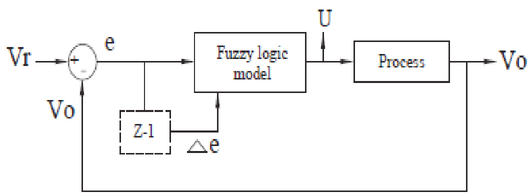


A fuzzy logic control scheme proposed for maximum solar power tracking of the PV array with an inverter for supplying isolated loads. They have such a robust & relatively simple to design since they do not require the knowledge of the exact model.[2]



A fuzzy logic controller for interfacing photovoltaic arrays with DC-DC converter has been developed. By applying the pulse width modulation (PWM) control scheme with appropriate MPPT algorithm to the power switches in the DC-DC converter that draws maximum power from photovoltaic array. The fuzzy [3]logic is an effective tool to track and extract maximum power to the isolated load compared to conventional PI and P&O methods.

ANALYSIS OF THREE PHASE AND SINGLE PHASE SELF-EXCITED INDUCTION GENERATOR

It is well known that the three phase induction machine can be made to work as a self-excited induction generator, provided capacitance should have sufficient charge to provide necessary initial magnetizing current. In an externally driven three phase induction machine, if a three phase capacitor is connected across its stator terminals, an EMF is induced in the machine windings due to the self excitation provided by the capacitor.[4]

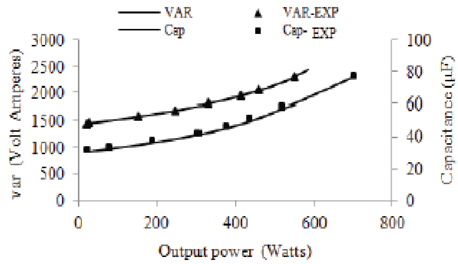
The flux produced due to these currents would assist the residual magnetism. This would increase the machine flux and larger EMF will be induced. This in turn increases the current and the flux. The induced voltage and current will continue to rise until the Var supplied by the capacitor is balanced by the var demanded by the machine, a condition which is essentially decided by the saturation of the magnetic circuit.

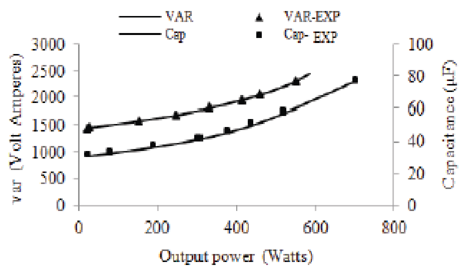
ANALYSIS OF THREE PHASE AND SINGLE PHASE SEIG

The steady state and dynamic characteristics of three phase and single phase SEIG are discussed in this section for various operating conditions.

Steady State analysis of three phase SEIG

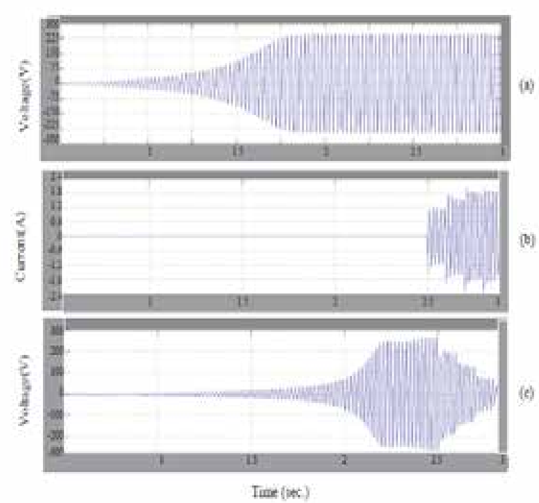
Fig. a shows variation of the var and capacitance with output power for constant terminal voltage at rated speed. For constant terminal voltage, the value of capacitance and var increases with output power. It may[5] also be seen that for an increase in output power of the machine at rated speed, the var has to vary continuously for regulating the terminal voltage.





Dynamic Analysis of three phase SEIG

The no load per phase voltage waveform across the load terminals is shown in Fig. a. The load is applied after the voltage build up to the steady-state level (230V) with a fixed excitation capacitance. It is observed from the current waveform Fig. b that when the load is increased, the load current also increases from 1.2A to 1.6A and hence the load voltage decreases from 230V to 200V Fig.c. If the load is further increased, again the load current increases from 1.6A to 1.8A, now the load voltage almost gets collapsed around 75V Fig. c. This is due to the fixed capacitance, which is not sufficient to meet the change in load.



Dynamic and steady-state analysis of three-phase and single phase SEIG has been discussed under no-load and loading conditions. From the three-phase and single phase SEIG characteristics it is observed that, the shunt capacitance and series capacitance has to be selected such that it has to meet the change in load. It is also observed that the system exhibits inherent protection for short circuit

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fault and re-excitation takes place after the removal of fault. The satisfactory performance of three-phase and single phase SEIG under dynamic and steady state shows the suitability of its applications in wind energy conversion system under isolated operation. Even though satisfactory performance has been observed in wind energy conversion, the wind potential is seasonal and continuous generation is difficult. Therefore a hybrid energy conversion system employing wind and solar can be utilized in isolated generation for an uninterrupted power generation.

CONCLUSION

In this research work, the characteristics of PV array, dynamic and steady state performance characteristics of three phase SEIG, single phase SEIG and hybrid schemes are presented in detail. The hybrid schemes are presented for solar-wind driven three phase SEIG, solar-wind driven single phase SEIG and solar-wind driven three phase SEIG with Vienna rectifier. For all the cases, a generalized fuzzy logic controller with simple rule base has been proposed. It is found that for all levels of irradiation and change in wind speed or both, the proposed fuzzy controller effectively works with the simple rule base formed.

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