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Fuzzy Controlled Mathematical Model For Sustainable Utility Interfaced Solar Power For Rural India

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Abstract

In most of Indian villages vocational literacy houses are run by NGO in community centres. These houses impart training in vocational trades to empower potential youth and provide them self/or wage employment. These houses need lighting and power sources to conduct vocational classes in centre. Although these houses are grid assisted and hence conventional grid powered inverters are kept as a standby to provide power supply in absence of grid failure. In these inverters power is drawn as a primary source from grid source even for small load and battery gets its charge as long as grid exists and thus lacks the sustainable feature under load shedding. In order to overcome the above constraint, a novel design of solar-grid powered inverter producing green electricity has been proposed as a primary source. The inverter has been designed to work always on battery mode for a period as decided by fuzzy controller. This is supplemented consistently by grid/or DG, as and when needed, under high load energy requirement. Thus the controller eliminate or minimizes the grid/DG dependability and at the same time reduces its connectivity with grid/DG to its maximum extend in an optimal way and thus provide 24 hour x 7 days power to these literacy houses. The PWM technology is used to charge the battery as well as to produce supply usable AC power to load with less harmonics, obtained and stored in battery bank from PV module. The use of dual battery bank for storing the PV energy and delivery of energy to load simultaneously are unique features of solar powered inverter to maintain sustainability.

Indexing terms/Keywords

Solar inverter; PWM charger; Fuzzy control; Total Harmonic Distortion (THD) etc.

Academic Discipline and Sub-Disciplines

SUBJECT CLASSIFICATION

TYPE (METHOD/APPROACH)

INTRODUCTION

Electricity is the basic need for lighting and powering electrical appliances in every houses/community centres but it reaches there with limited supply. The further expansion of conventional sources has become almost standstill due to diminishing trend of fossil fuels. Government of India is taking initiative to electrify Indian villages with non conventional sources. Literacy houses have been proposed to establish in almost every District where potential youth may utilize their time to improve their skills or form new skills. In order to provide electricity, many standalone and utility interfaced hybrid power supply system have been developed using renewable energy sources in the past but sustainability and optimal use of grid /DG with minimum operational time have not been considered and thought much. Although an autonomous PV system backed up with battery alone can meet most of the energy demand but cannot meet the entire need of energy demand of a rural house/community centres due to its large size and high investment cost. To provide a continuous form of power generation and its supply, an integrated hybrid system with grid and DG source are the only viable option as supplementary source with its optimal operation. [1-6].

In the proposed scheme, the design of fuzzy controller based grid interfaced inverter has been proposed for supplying power to a literacy centre in villages in order to optimize the use of grid connectivity i.e the operational time which not only reduce the cost of electricity generation in most efficient way but also cause less impact of environmental problem on the life of villagers. PV energy plays a role of distributed primary energy source which meet almost all the base and critical load requirement of a rural house running community literacy centre. A diesel generator is the supported energy source to generate energy during peak load hours of a day as well as to compensate the deficit of grid power or PV energy (stored in the battery) - arises due to varying insulation during low sun radiation period/cloudy weather day. The socio-economic impact on life style of potential youth has been carried out as a case study to validate for the minimal use grid/DG and evaluate the performance of the system at site.

2. SYSTEM MODEL DESCRIPTION

The solar home light model consists of the following units as shown in Fig.1 which include:

- Solar PV module with dual Battery Bank
- Intelligent control unit Grid/DG Network

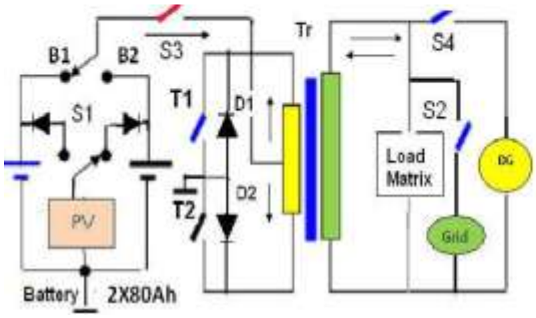

Fig 1: Power Circuit and Prototype System Module

The primary source of power supply to rural literacy houses or community centres is the PV power stored in the battery. Load power is managed either by battery back up PV system or supplementary sources i.e grid/DG source integrated with PV system. The power converter unit of the PV system takes the low 12V DC voltage input from PV backed up energy source, stored in battery bank, as shown in **Fig.1** and convert it into usable 220VAC, 50 Hz 300W/750VA output with the help of a transistorized centre tapped transformer (Tr) based push-pull configured BJT/MOSFET bi-directional converter (inverter) circuit. The controller circuit generates PWM square wave control pulses, using IC CD 4047 based 50Hz oscillator, to activate and switch on IRF 540 MOSFET/2N3055 transistors T1 and T2 alternatively producing AC PWM voltage with low THD at the output of secondary of transformer across the load. DG set is connected to load when the stored PV energy falls below load energy in absence of grid or when the battery reaches a discharge cut off level of 10.4V and remain on till battery attain a charge level to match with load energy requirement in the range of 12.8V to 13.4V. The intelligent,adaptive control action of the controller performs load power/energy management and thus monitor and manage to deliver continuous power to load. The charging operation is performed either by PV source through one unit of battery Bank and another unit by grid/DG source through bidirectional converter circuit in its rectifying mode (comprising of diodes D1 and D2 while transistor T1 and T2 remain off). The intelligent controller prevents the battery to go into deep discharge/or overcharge as the case may be and thus battery never allows attaining a cut-off low voltage of 10.4V for deep discharge condition or 13.4V on the upper limit , in case of overcharging.

The system is designed for a Literacy vocational centre as per load energy requirement with the specifications as given below:

Load Energy = 1800 – 3600 Watt-hours over a period of 24 hour, with a demand factor of 0.9 and 50% sharing with grid power.

PV size = 4 x 75 W_p, 12 V

Battery Size = 2 x Dual 80 Ah, 12V low self discharge inverter grade tubular lead acid battery.

Load(s) = CFL lamps, Fans, TV and Rural Industrial equipment including pump etc.

Converter = 300 W/750 VA, 12 DC ~ 220 V SPWM AC , 50 Hz (Distortion 5- 15%)

Grid/DG set = Grid distributed network/Portable LPG 2x550VA/Diesel based 1.5 KVA

3. FUZZY CONTROL SYSTEM MODEL AND CONTROL ALGORITHM

The control strategy for an integrated power system is a control algorithm for the interaction among various system components as shown in Fig 1. The system controller determines the switching ON of grid supply or in case of grid failure, starting/stopping of the diesel generator, for feeding power to load as well as charging battery operation. The inputs of the controller are the parameters such as un-predictable load power and renewable varying output solar energy stored in battery, whereas output parameter is the switching ON / OFF grid /diesel generator. A power control strategy is also needed to control the flow of power and to maintain adequate reserves of energy during operational period continuously in the battery storage devices. The fuzzy based technique/ has been implemented in the control strategy to achieve optimal minimal operation to draw power either from grid /or DG resulting in saving on cost of electricity or due to less fuel consumption Fig. 2.

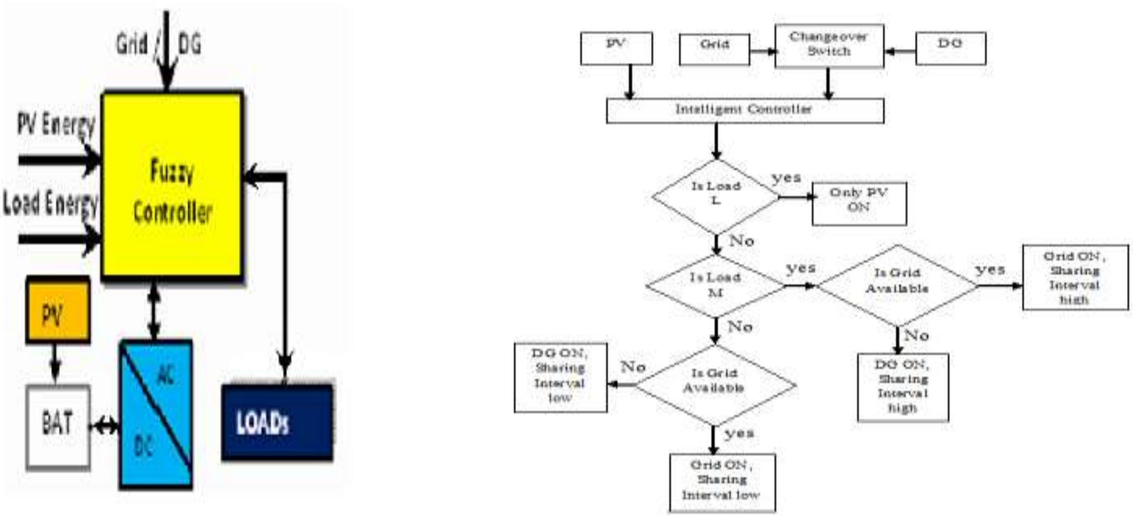

Fig.2: Fuzzy Control Technique (Left) and Algorithm (Right)

Fuzzy logic control has been used as an intelligent tool to integrate and manage energy sources to flow in the system in such a way that it meet the load power requirement in optimal way under varying load condition.. The procedure in making the control designs are setting the constraints, assigning the linguistic variables and setting the rules for the fuzzy controller. Solar radiations and load(s) are the areas that affect the studied outputs and hence load demand and the solar (PV) energy stored in battery are considered to be the input variables. The output variable of this controller is the duty cycle of operation or i.e turn-on time (power sharing) period of the grid or generator at each sampling period of one hour depending on the battery charging status as decided by fuzzy control action.

Input variable : Load and PV stored energy 3600Whour

Load Energy (300 -1kW)) @ one hour

Low : Trimf (0 25 50)

Medium : Trimf (25 50 75)

High : Trimf (50 75 100)

PV Stored Battery Energy (10.4 V – 13.4V)

Low : Trimf (0 25 50)

Medium : Trimf (25 50 75)

High : Trimf (50 75 100)

Output variable: grid /DG operational time (%)

Grid /DG System

Z : Grid/DG (Low op- time power sharing) : Trimf (0 25 50)

M : Grid/DG (Medium Op-time power sharing) : Trimf (25 50 75)

P : Grid/DG on (High op- time Power sharing) : Trimf (50 75 100)

4. FUZZY RULE OUTPUT

Knowledge based decisions, based on the input conditions of battery stored energy as well as demand for load Energy, have been formulated and computed from fuzzy tool and shown in Table 1. The rule based outputs are represented as follows:

Table 1: Fuzzy Rule for control action

Battery Load	**Small**	**Medium**	**High**	**Remarks**
Small	M(1)	P(4)	P(7)	The meanings of the labels designating the names of linguistic values are : L : load Energy, B: PV Stored Battery Energy, S : Small, M : Medium, H: High, Z: Low power sharing, M : Medium power sharing. P: High Power sharing
Medium	Z(2)	M(5)	P(8)	
High	Z(3)	M(6)	Z(9)	

The output result i.e. P, M or Z activate the grid/DG to switch it ON /or OFF respectively for a period evaluated as a crisp value at an interval of one cycle period of operation of 24 hours.

4.1 Computational of operational time in % and simulated result using fuzzy tool

As a case study for typical demand of load power acquired from the site with the present status of energy stored in the battery status has been discussed. The corresponding membership function for the given status are as follows:

Case-I:

Load energy (70%) ---- Medium (0.16) & High (0.82)

Battery energy (30%) ---- Low (0.23) & Medium (0.75)

Rules fired are 4, 5, 7 and 8.

Strength of rule 4 : [M(0.16) ∩ L(0.23)] = 0.16 , Strength of rule 5: [M(0.16) ∩ M(0.75)] = 0.16

Strength of rule 7: [H (0.82) ∩ L(0.23)] = 0.23 Strength of rule 8: [H(0.82) ∩ M(0.75)] = 0.75

Case-II:

Load energy (30%) --- Low (0.76) & Medium (0.23)

Battery energy (70%) --- Medium (0.22) & High (o.87)

Rules fired are 2, 3, 5 and 6.

Strength of rule 4: [L(0.76) ∩ M(0.22)] = 0.22 Strength of rule 5: [L(0.76) ∩ H(0.87)] = 0.76

Strength of rule 7: [M (0.23) ∩ M(0.22)] = 0.22 Strength of rule 8: [M(0.23) ∩ H(0.87)] = 0.23

Case-III:

Load energy (50%) ------Medium (1.00)

Battery energy (50%)---- Medium(1.00)

Rules fired is 5

Strength of rule 5: [M (1.00) ∩ M(1.00)] = 1.00

4.3Defuzzification Crisp Value:

An accurate and standard method known as CENTROID Method has been used in computing the crisp value [7].

Table 2. Results

Cases	Calculated Result	Simulated Result
Case I	71.92%	69%
Case II	32.86 %	31%
Case III	50 %	50%

5. RESULTS AND DISCUSSION

5.1 Validation of Output Controlled Parameter with MATLAB Simulation Tool

The load sensitivity analysis has been carried under varying energy storage status of battery. Energy flow takes place when battery stored energy remain more as compared to load demand otherwise power is shared with grid/DG for the time period as decided by fuzzy control action.

The Fig. 3, reflects the input and output as % of operational ON period of grid/DG of its full value i.e 69 % for one such set of above conditions as Load Energy = 70% and Battery Energy status = 30% (assume grid is unavailable and power is shared by DG).

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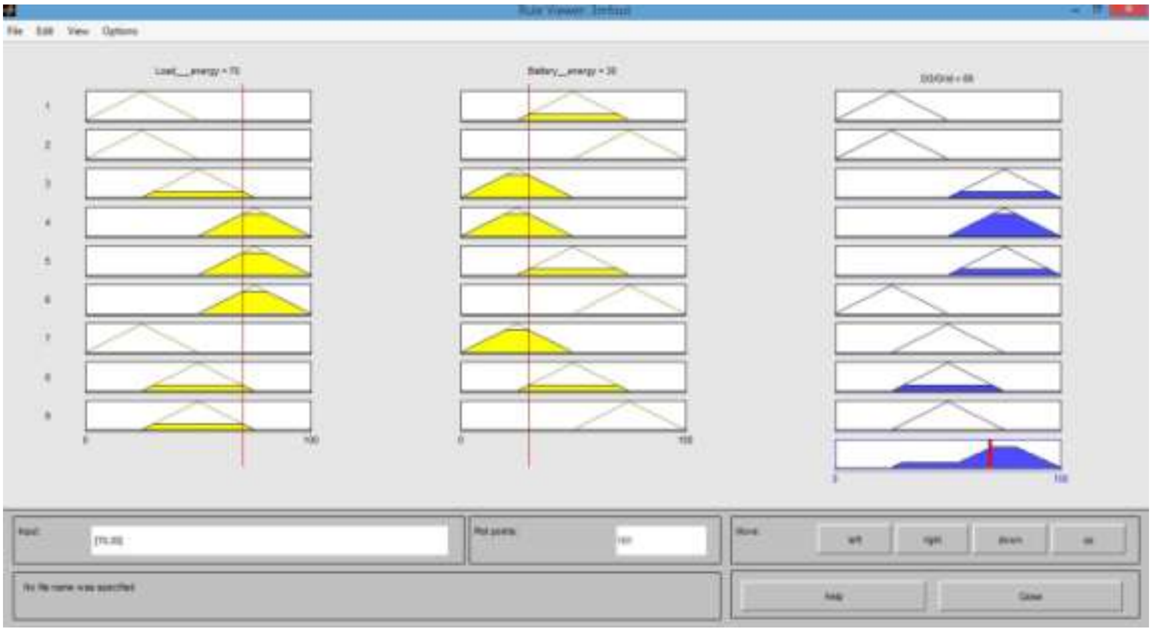

Fig. 3: Rule Viewer

5.2 Power Saving and working economy

Average monthly PV energy shared with grid/DG in terms of operational time has been depicted below. The cost analysis of electricity generation for PV system as well DG power system during its Life cycle period reflect the pay-back period which comes out to be approximately 5-6 years when the cost of electricity reduces and become at par with the cost of electricity of grid (utility) supply. (Fig. 4)

Month	Grid /DG Op-Time Saving (%)	Month	Grid /DG Op-Time Saving (%)
Jan' 11	40/60	July'09	40/60
Feb	45/55	Aug	35/65
March	40/60	Sept	40/60
April	50/50	Oct	45/55
May	50/50	Nov	50/50
June'09	40/60	Dec' 11	40/60

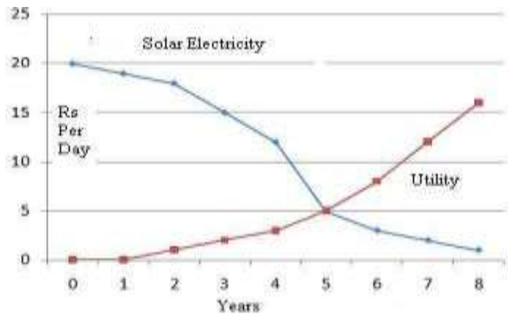

Fig 4: Power saving (Left) and Pay back period i.e Cost of Electricity (Right)

6. CONCLUSION AND FUTURE WORK

In this innovative project study, the design of a novel fuzzy control scheme for an integrated grid/DG interfaced solar powered inverter has been developed with an objective to save grid power and creating a pollution free environment in village literacy house, the scheme was implemented in a Vocational Literacy centre and found a good impact in society.

ACKNOWLEDGMENTS

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