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A novel proton exchange membrane fuel cell based power conversion system for telecom supply with genetic algorithm assisted intelligent interfacing converter

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ABSTRACT

This paper presents the fuel cell based simple electric energy conversion system for supplying the telecommunication towers to reduce the operation and maintenance cost of telecom companies. The telecom industry is at the boom and is penetrating deep into remote rural areas having unreliable or no grid supply. The telecom industry is getting heavily dependent on a diesel generator set and battery bank as a backup for continuously supplying a base transceiver station of telecom towers. This excessive usage of backup supply resulted in increased operational expenditure, the unreliability of power supply and had become a threat to the environment. A significant development and concern of clean energy sources, proton exchange membrane fuel cell based supply for base transceiver station is proposed with intelligent interfacing unit. The necessity of the battery bank capacity is significantly reduced as compared with the earlier solutions. Further, a simple closed loop and genetic algorithm assisted controller is proposed for intelligent interfacing unit which consists of power electronic boost converter for power conditioning. The proposed genetic algorithm assisted controller would ensure the tight voltage regulation at the DC distribution bus of the base transceiver station. Also, it will provide the robust performance of the base transceiver station under telecom load variation and proton exchange membrane fuel cell output voltage fluctuations. The complete electric energy conversion system along with telecom loads is simulated in MATLAB/Simulink platform and verified theoretically. The successful implementation and the obtained results illustrate the feasibility of the proposed system for reliable operation of the telecom towers.

1. Introduction

Telecommunication services are a valuable tool for socio-economic development of the nation. It not only fulfills the basic need of communication but also play a significant role in modernization and rapid growth of other sectors of the economy. In India, the telecom industry has grown exponentially to emerge as world's second largest telecom market in past two decades with more than 944.01 million mobile phone users facilitated by 700,000 telecom towers across the country [1]. As telecom industry is already at the boom and with the roadmap laid by the policies of the department of telecommunication (DoT) would continue to expand in near future with deep penetration in remote rural areas. The current status of rural teledensity is approximately 46.14%, and national telecom policy (NTP) has set the target to achieve 100% by the year 2020 [2]. In this path of growth and projection of telecom industry, the foremost challenge is to provide the supply to base transceiver station (BTS) of telecom tower in remote rural areas where around 5% villages are not electrified. Since, telecom industry requires an uninterruptible reliable power supply to provide quality service to the customer without rolling out of services [2]. At present scenario, around 70% of the telecom towers don't get the continuous, reliable supply from state electricity boards. Fig. 1 gives the status of grid availability (in an hour) per day in different states of India [1].

Conventionally, diesel generator (DG) has been used to supply power to BTS during non-availability hours of grid supply. Since, DG has a startup failure rate of 15%, therefore the battery bank must be employed for the backup power supply [3]. The excessive use of conventional power supply having DG and battery bank

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Nomenclature

A	cell area, cm^2
BTS	base transceiver station
C	capacitance, mF
D	duty ratio of the boost converter
DG	diesel generator
DoT	department of telecommunication
e(t)	error signal
E_{nerst}	Nernst potential of single cell, V
FC	fuel cell
f_S	switching frequency, kHz
GA	genetic algorithm
I	cell current, A
i_{den}	current density, A/cm^2
$i_{limit,den}$	limiting current density, A/cm^2
K_P	proportional gain
K_I	integral gain
L	inductance, mH
NTP	national telecom policy
OPEX	operational expenditure
p_{H_2}	partial pressure of hydrogen, atm
p_{O_2}	partial pressure of oxygen, atm
$p^{st}_{H_2O}$	saturation of water vapor, atm
p_a	anode inlet pressure, atm
p_c	cathode inlet pressure, atm
PEMFC	proton exchange membrane fuel cell
PI	proportional integral controller
POL	point of load
R	load resistance, Ω
R_C	resistance, Ω
R_M	equivalent resistance of membrane, Ω
RH_a	relative humidity of vapor in anode
RH_c	relative humidity of vapor in cathode
RHP	right hand complex plane
r_L	internal resistance of the inductor, Ω
$r_{C,}$ ESR	internal resistance of the capacitor, Ω
SMPC	switched mode power converter
TRX	transceiver
T_S	switching period, s
T_{cell}	cell temperature
u(t)	control signal
V_{in}	input voltage to the boost converter, V
V_o	output voltage of the boost converter, V
V_{ref}	reference voltage, V
x	state variable
$\dot{x}$	derivative of the state variable
y	output state variable
Y_1, Y_2, Y_3, Y_4	parametric coefficients of the cell
ZN	Ziegler and Nichols
η_{mt}	mass transfer loss
η_{act}	activation loss
η_{ohm}	ohmic loss
ρ	specific resistivity of membrane for electron flow, Ω cm
β	concentration loss constant, V

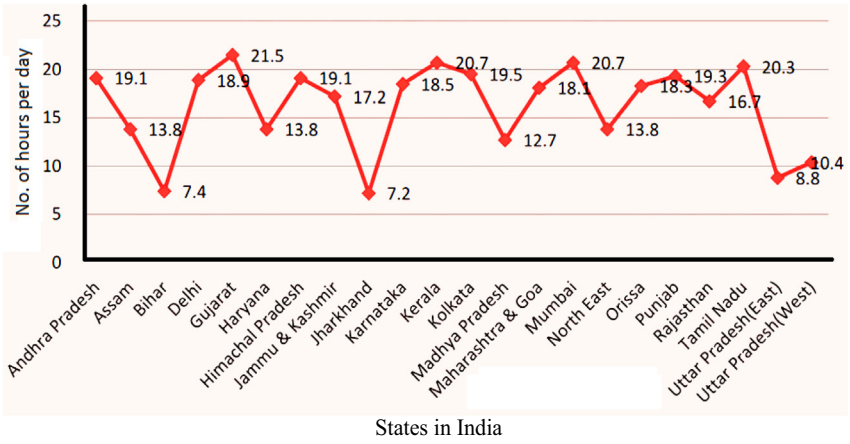

Fig. 1. Grid availability in different states of India per day (hours).

increased the operational expenditure (OPEX) of telecom companies which includes cost of diesel as fuel, transportation, regular maintenance visit and replacement of batteries (have shorter lifespan) [3,4]. Further, massive dependence on conventional supply pose grave threat to environment as its operation adds to global carbon emission by producing greenhouse gas i.e. CO_2 [5].

Considering DG operation as an environmental threat, DoT has taken the 'green telecom' initiative to upgrade 50% of urban telecom towers and 100% rural telecom towers to be powered by the hybrid power supply. The initiative encourages the use of renewable energy resources along with grid utility to reduce the carbon credits of telecom sector by 8% in the year 2019 [2]. Renewable resource such as solar PV generator and wind energy conversion system (WECS) are proposed for power supply system with DG as backup in the literature [6,7]. The PV and WECS are intermittent in nature, thus, additional energy system is mandatory to improve the reliability of the power supply. The spring based storage is used in distributed power generation for sub-tropical climate conditions incorporating a sterling engine driven solar thermal unit and hybrid vertical axis wind turbine in Ref. [8]. Also, lithium-ion battery based storage is implemented with PV solar home system in areas where kerosene lamps are used for lighting [9]. To find a reliable power supply for BTS, the potential of fuel cell is being explored which has higher conversion efficiency, no pollutants to the environment and simple maintenance. The fuel cell combines the best features of reciprocating engines and batteries. Therefore, the challenges posed by PV and WECS in terms of intermittent nature, fuel cell are an attractive solution for the long term backup on