DESIGN OF SMART CONTROLLERS FOR ACTIVE DISTRIBUTION SYSTEMS

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by

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CERTIFICATE

This is to certify that the thesis entitled "**Design of Smart Controllers for Active Distribution Systems**" being submitted by **Mr. Chandrasekhar Perumalla** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology Delhi.

Mr. Chandrasekhar Perumalla has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results obtained here, have not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

A coordinated control philosophy, for load balancing leading to frequency stabilisation, of an active distribution system with solid oxide fuel cell (SOFC), photovoltaic (PV) generator, diesel engine driven synchronous generator (DEG), some critical and noncritical loads, under islanded operation is proposed in this thesis. Due to delay involved in hydrogen production cycle, SOFC cannot respond to load transients immediately when it is the only source to feed the load. Hence, it needs to be augmented with some quick responding storage elements like battery/capacitor as energy buffers. A detailed model of SOFC with a battery, an integral part of the considered active distribution system, is proposed in this thesis. As the output of SOFC and PV is DC, a feedback linearized sliding mode controller (FBLSMC) based voltage source inverter (VSI) is developed to interface with the AC system. A simplified tuning procedure, which is not adequately addressed in the literature, has been formulated in this thesis for the selection of SMC parameters. The developed FBLSMC performance is examined for control of SOFC power under different disturbances and has been extended to a multiple SOFC scenario using the Master-Slave approach.

On the other hand in case of PV based system the same control approach (FBLSMC) need to be supplemented with maximum power point (MPP) tracking (MPPT). Even though perturb and observe (P&O) based MPPT is widely accomplished and in use for a long time, its parameters design is still an open question for which a generalized design criterion has been proposed in this thesis. To overcome the sluggishness of P&O based trackers and operating point dependency of recently proposed adaptive incremental conductance (INC) based trackers, a TS fuzzy based INC tracker (TSFINC) has been proposed in this thesis. The superiority of the

proposed tracker is demonstrated against the well designed P&O and recently proposed adaptive INC based MPP trackers through numerical and experimental validations. However, for slowly changing insolation scenarios, its performance is not so encouraging whereas the P&O and adaptive INC based trackers are delivering unacceptable performance. In this connection, a methodology in which the tracking is independent of the slope of PV generator output and rate of change of insolation, termed as *adaptive-predictor-corrector* based MPP tracker is proposed in this thesis and its performance has been further improved using artificial neural network (ANN).

At last, a novel control philosophy is designed for the frequency regulation of a storage-free DEG-PV-SOFC hybrid ac microgrid with all the sources in the frequency control service (FCS) mode except the PV which can toggle to MPPT based on whether the demand response control (DRC) is activated or not. Since, PV is a fast acting sources and is also participating in FCS mode through *derating* there is no need of any storage such as battery, super capacitor and fly wheel to improve the frequency response.

The PV generator is controlled by a *neuro-fuzzy* controller developed using the proposed ANN based adaptive-predictor-corrector MPPT algorithm. The ANN has been trained to generate two voltage references, one is for MPPT and other is for 90% of maximum power output so as to have a reserve of 10% to support the frequency response. A PV first, followed by SOFC and DEG philosophy is adopted in the frequency control approach keeping in mind that the DEG should always produces the minimum required power. The control loop is so developed that the PV keeps always 10% margin unless otherwise the DEG and SOFC are exhausted with their capacity. The DRC is called for only when the PV reaches its MPP in the control procedure.

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