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An Efficient Power Factor Maximization Model with Buk-Boost Converter in Power Systems

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Abstract: The problem of power management in power systems has been well studied. There exist number of approaches towards power handling which consider input voltage, residual voltage in different capacitors and uses different converters to maximize the output voltage. However, the methods suffer to achieve higher performance in voltage stabilization in power systems. To handle this issue, an efficient buck boost converter based power factor maximization model (BBC-PFM) is presented in this paper. The model fabricated with k number of buck boost converter in serial. According to the design, the method generates voltage ensemble where each has different voltage slots and values. A slot in voltage ensemble represents the residual voltage in specific converter. Accordingly, there will be number of ensembles will be generate based on the switching conditions. Generated voltage ensembles are used to perform circuit selection and based on that a small set of converters are triggered to discharge the voltage to support power system, where rest of them are triggered to get charged. The selection of converter is performed by computing Power Factor Maximization Support (PFMS) which is being measured based on the voltage in inductor, capacitor present in any ensemble with the input voltage. The proposed method improves the performance of power factor maximization with less voltage loss.

Keywords:Power Systems, PFM, BBC-PFM, PFMS, Voltage Ensembles.

1. Introduction:

The modern world runs with electricity and it is power which leads the entire world. Power generation has been identified as a key factor to support the human life. As the humans uses variety of electric devices for their support and the electric systems needs a constant voltage for their running. But in reality, the voltage produced by any source will not be a constant one and there will be fluctuation in the electricity produced. Regulating a constant electric power is essential for any electric device. To handle such fluctuation, there are number of devices available like inverter which being connected with the power system

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would support the constant voltage regulation. However, there are number of constraints must be considered in designing any power system.

Different converters are available to convert DC-DC voltage which supports the smooth regulation of voltage for the power systems. The converters like cuk converter, boost converter are fabricated in different power systems. The only issue behind the adoption of such converter is the voltage loss. But in any power system, the voltage should be saved for the next duty cycle. By doing so, the performance of power systems can be improved. The buck boost converter has been identified as most efficient one which produces less voltage loss. The circuit diagram of buck boost converter is presented in Figure 1.

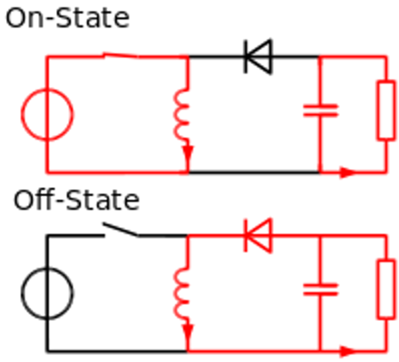

Figure 1: Circuit Diagram of Buck Boost Converter.

The buck boost converter works in two modes. In the on state, the voltage source connected with the inductor (L), which accumulate the energy in the inductor and the capacitor goes to discharge mode to supply energy to the output load. On the other state named off state, the inductor is connected to the output and which in turn allows the capacitor to get charged. This design supports the excess voltage to be accumulated with the capacitor which in turn would support the output voltage at the other duty cycle.

This article presents a novel power factor maximization model with the buck boost converter. The model has number of converters connected in serial to support the output load. The model generates number of ensembles according to the input load, converters with on off state and output load. The model computes PFMS value for different ensemble to identify the most optimal circuit to support the output voltage. The complete working of the model is sketched in the section 3.

2. Related Works:

Number of designs and methods are discussed in literature and this section details some of the methods around the problem.

An adaptive state estimation model is presented in [1], which uses GaussianLaplacian Mixture (GLM) model to fit body and tail of unknown distribution. Also, the method uses expectation maximization scheme.

An adjustable multimode monitoring with hybrid variables (AMMHV) model is presented in [2], which uses expectation maximization towards parameter estimation of unknown label is received.

A voltage source converter based multi terminal high voltage direct current (VSC-MTDC) model is presented in [3], which is capable of handling frequency disturbances.

Aadaptive reference based voltage control is presented in [4], to perform autonomous DC voltage regulation and power-sharing.

A superconducting magnetic energy storage (SMES) integrated current-source DC/DC converter (CSDC) is presented in [5].

A stochastic game approach is presented in [6], towards distributed voltage regulation in autonomous PV prosumers.

A model predictive control (MPC) is presented in [7], which uses wind farms (WF) as black-start (BS) source to start up a thermal generating unit.

A grid voltage modulated direct power control (GVM-DPC) is presented in [8], towards power regulation in grid connected voltage inverters. A new coordination strategy is presented in [9], which uses DPC and vector current control (VCC).

Prosumer orient Voltage Regulation model is presented in [10], which combines Coordinated Real and Reactive Power Control units.

The voltage stability in microgrids are analyzed in [11], which uses Bifurcation theory to identify the behavior of the system.

A bilevel voltage regulation scheme is presented in [12], to support self operated microgrids.

A hybrid voltage control scheme is presented in [13], to support series type inverters.

A distributed secondary control scheme is presented in [14], to handle voltage regulation and power sharing in microgrids.

3. Buck Boost Converter Based Power Factor Maximization (BBC-PFM) Model:

The proposed model monitors the incoming voltage at each duty cycle. Also, the method maintains the trace of circuits being switched on and the converters being set for on state and off state [15]. Using the trace, the method generates number of ensembles. According to the input voltage, the method computes PFMS value for each ensemble generated. The value of PSMS is measured based on the average residual power in the inverter and capacitors with the input voltage, number of circuits to be triggered and so on. Based on the value of PFMS, the method identifies a unique ensemble to perform power support. The rest of the converters are triggered to off state [16].

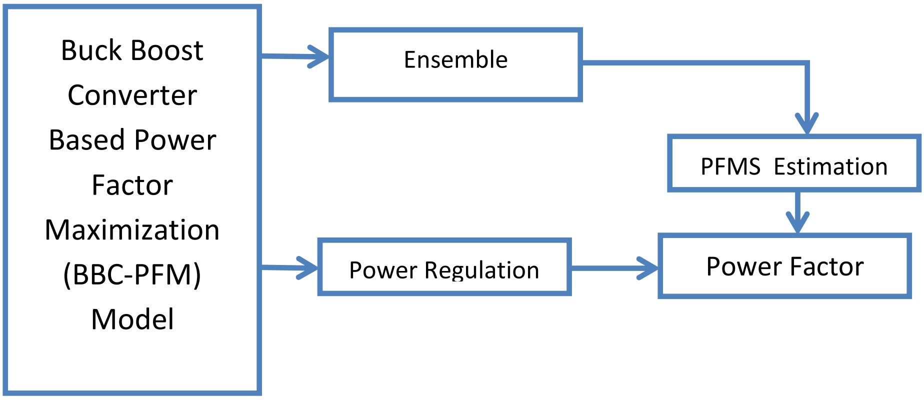

Figure 2: Architecture of BBC-PFM model

The working model of proposed BBC-PFM is presented in Figure 2, where each function has been detailed in this section.

Ensemble Generation:

The proposed method maintains the trace of circuits and their condition in each duty cycle. Using the trace, the method identifies the set of converters in the system and their condition with the residual voltage. According to the inductor and capacitors with their voltage conditions, the method generates number of combinations. Each combination has been identified as an ensemble. Generated ensemble has been added to the set which has been used to perform power factor maximization.

```
Algorithm:
Given: Circuit C
Obtain: Ensemble set Es.
Start
    Read c.
    Converter set Cs = $\sum Converters \in C$
    Initialize Ensemble set Es.
    For each size s
        Generate converter set Cons = $\overset{size(Cs)}{\underset{i=1}{Random(Cs)}}$
        Combination set Coms = Generate Combinatory (cons)
        Add to Es = $\sum Ensembles(Es) \cup Coms$
    End
Stop
```

The ensemble generation algorithm generates number of possible combinations of circuits and adds to the ensemble set. Generated ensemble set has been used to perform power factor maximization.

PFMS Estimation:

The power factor maximization support is the measure which represents the efficiency of any circuit pattern or combination of converters to support output voltage efficiently. It has been measured based on the voltage available in the inductor and the capacitor. Also, with the combination of switching pattern, the method computes the value of PFMS. It has been measured according to the voltage residual and voltage required and number of circuits can be charged and discharged. Based on the value of PFMS, the method performs power factor maximization.

```
Algorithm:
Given: Ensemble E
Obtain: PFMS.
Start
    Read E.
    Identify non triggered converters Ntc $=\sum_{i=1}^{size(E)} E(C).State == off$
    Compute average residual voltage Arv = $\frac{\sum_{i=1}^{size(Ntc)} Ntc(C).volts}{Size(Ntc)} \times \frac{1}{3}$
    Compute Average charging volts Acv = $\frac{\sum_{i=1}^{size(E)} E(C).volts\ where\ E(c) \ni NTC}{Size(E)} \times \frac{1}{3}$
    Compute PFMS = $\frac{Arv}{Acv} \times \frac{inputvoltage}{OutputVoltage}$
Stop
```

The PFMS estimation algorithm computes the value of PFMS according to the average residual value of converters which were in the off state and average charging value measured according t the voltage available in the inductors. Estimated value of PFMS is used to perform power factor maximization.

Power Factor Maximization:

The power factor maximization algorithm monitors the incoming voltage and generates ensemble sets according to the number of converters connected in serial. For each ensemble circuit, the method computes the value of PFMS. Based on the value of PFMS, the method identifies a suitable one with least dischargers and maximum chargers. Selected circuit pattern has been triggered to manage the output voltage.

Algorithm:

```
Given: Circuit Trace CT, input voltage Iv
Obtain: Null
Start
    Read CT and IV.
    Ensemble set Es = Ensemble Generation (Circuit)
    For each ensemble En
        PFMS = PFMS Estimation
    End
    Circuit Ensemble CE = Choose Max valued PFMS with Least discharging Circuits.
    Perform regulation.
Stop
```

The proposed power factor maximization algorithm estimates PFMS value for different ensemble generated to identify the most optimal one and trigger the circuit pattern.

4. Results and Discussion:

The proposed buck boost converter based power factor maximization model has been implemented and simulated using Simulink. The performance of the model has been evaluated under various conditions and presented in this section.

Parameter	Value
Tool used	Simulink
Number of converters	20
Number of input voltage	5
Simulation Time	10 minutes

Table 1: Experimental Setup

The experimental setup used to evaluate the performance of the model is measured and presented in Table 1.

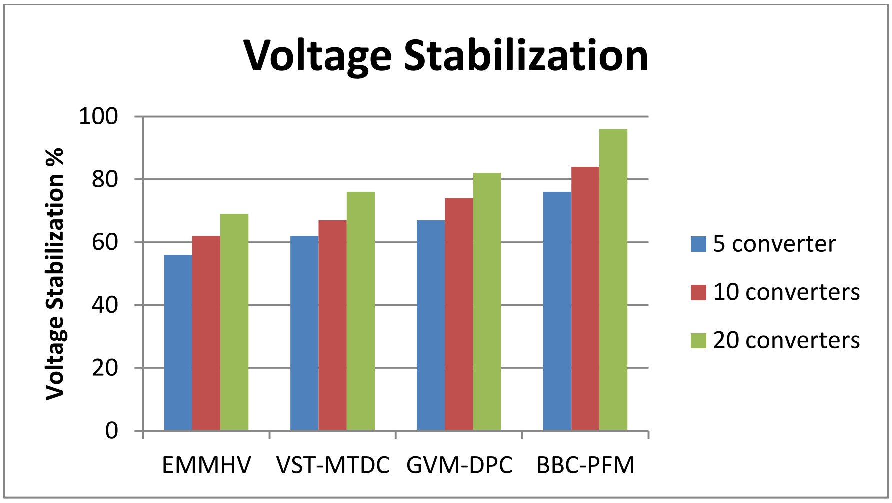

Figure 3: Voltage stabilization performance

The voltage stabilization performance produced by different methods are measured and compared in Figure 3. The proposed BBC-PFM model introduces higher performance than others.

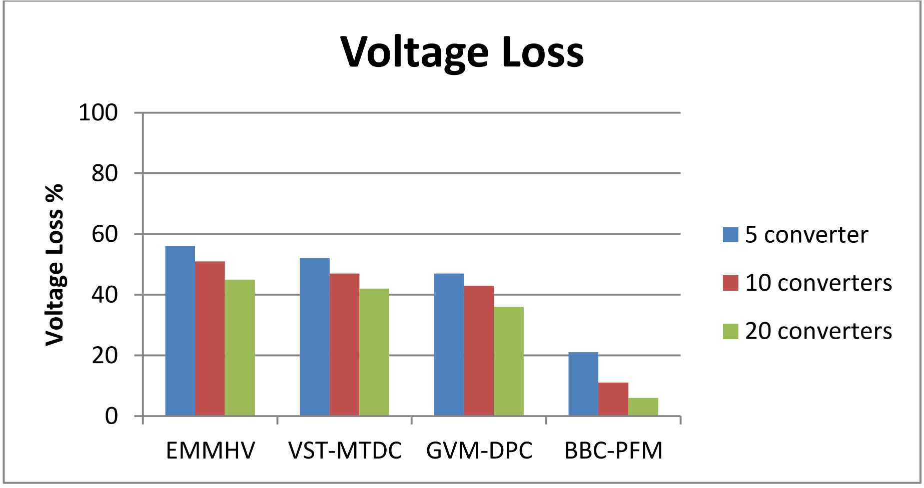

Figure 4: Voltage loss

The voltage loss introduced by various methods are measured and presented in Figure 4. The proposed BBC-PFM model introduced less voltage loss in all the cases.

5. Conclusion:

This paper presented a novel buck boost converter based power factor maximization model to support power systems. The method maintains the trace of circuits being switched on and the converters being set for on state and off state. Using the trace, the method generates number of ensembles. According to the input voltage, the method computes PFMS value for each ensemble generated. The value of PSMS is measured based on the average residual power in the inverter and capacitors with the input voltage, number of circuits to be triggered and so on. Based on the value of PFMS, the method identifies a unique ensemble to perform power support. The proposed method improves the performance of power factor maximization with less voltage loss.

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