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Comparative Study on Thermal Management Schemes with Waste Heat Recovery from Electric Vehicle Power Train

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In cold weather conditions (e.g. < 0 degree Celsius), a considerable amount of heating power is needed to satisfy the thermal comfort of vehicle passengers. This heating power, if obtained from positive temperature coefficient (PTC) resistors, can consume significant amount of energy stored in electric vehicle (EV) batteries, thus dramatically penalizing its drive range. To extend EV drive range without sacrificing the thermal comfort, the waste heat from the EV powertrain system can be recovered through heat pump operation of the vehicle air conditioning system which couples the powertrain coolant circuit with the refrigerant circuit. However, the amount of available waste heat is found to be inadequate to heat the cabin to the desirable temperature in cold weather conditions. Therefore, a thermal management scheme which utilizes both the ambient heat and the waste heat is proposed to reduce the total energy consumption and thus improve the vehicle drive range. Three thermal management schemes, utilizing the ambient heat only, the EV power train waste heat only and the dual heat sources, are quantitatively evaluated and compared over the WLTC driving cycle at various ambient temperature conditions by comprehensive simulations in KULI environment. Compared to the ambient heat only scheme, the dual heat sources scheme can work at lower temperatures, exhibits higher heating power and thus takes less time to reach thermal comfort temperature, and also has higher net energy gain. Compared to the waste heat only scheme, the dual heat source scheme can satisfy the thermal comfort without introducing new key components, has much higher heating power, and also higher net energy gain. It is also found that the net energy gain, defined as the ratio of the heating energy obtained from the heat pump operation to the total energy consumption over the WTLC, decreases with the increase of ambient temperature since the required energy for thermal comfort is lower at higher ambient temperature. This comparative study provides useful assessment for the selection of a suitable thermal management scheme for electric vehicles.